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Electrification of a portion of the Orleans Company's System, [1]

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Figs. 1 to 18, pp. 2 to 23.

The Orleans Company completed in 1900 the electrification of the double-track underground line linking the Austerlitz and Quai d'Orsay stations, and in 1904 extended electric working to the suburban service between Austerlitz and Juvisy. These conversions on the 600-volt direct-current system were completely successful, as were also the contemporary conversions of the Paris Metropolitan and State Railways (Invalides-Versailles line) which were carried out under similar technical conditions.

The traffic on the suburban line in question already exceeds 10 millions of tonne-kilometres (tkm.) per kilometre (9 842 000 Engl. ton-miles per mile) of the double-track. This important service is maintained by 18 electric locomotives of 1 000 H. P. to 2 000 H. P. each, and 7 motor-coaches each of 700 H. P.. The total kilometrage run per annum on this short section of 23 km. (14.3 miles) is 45 000 km. (27 960 miles) for the locomotives and 75 000 km. (46 600 miles) for the motor-coaches.

In spite of the excellent results of this initial electrification, it was not possible to proceed with any of the numerous schemes for extending electric working, which had been prepared before the War.

In particular, independent studies had been made in 1910 of the electrification of the Paris-Orleans line using steam power stations, and of the lines of the Central Plateau, based on the use of hydro-electric power stations. But these investigations were not pursued owing to the apprehensions which then existed with regard to electricity. Moreover, fuel prices ruling at that time rendered the financial aspect of electrification far from attractive.

(1) From « Electrification partielle du Réseau de la Compagnie d'Orléans » (« Electrification of a portion of the Orleans Company's System »), by Mr. PARODI, published as a series of articles in the *Revue générale des Chemins de fer*.

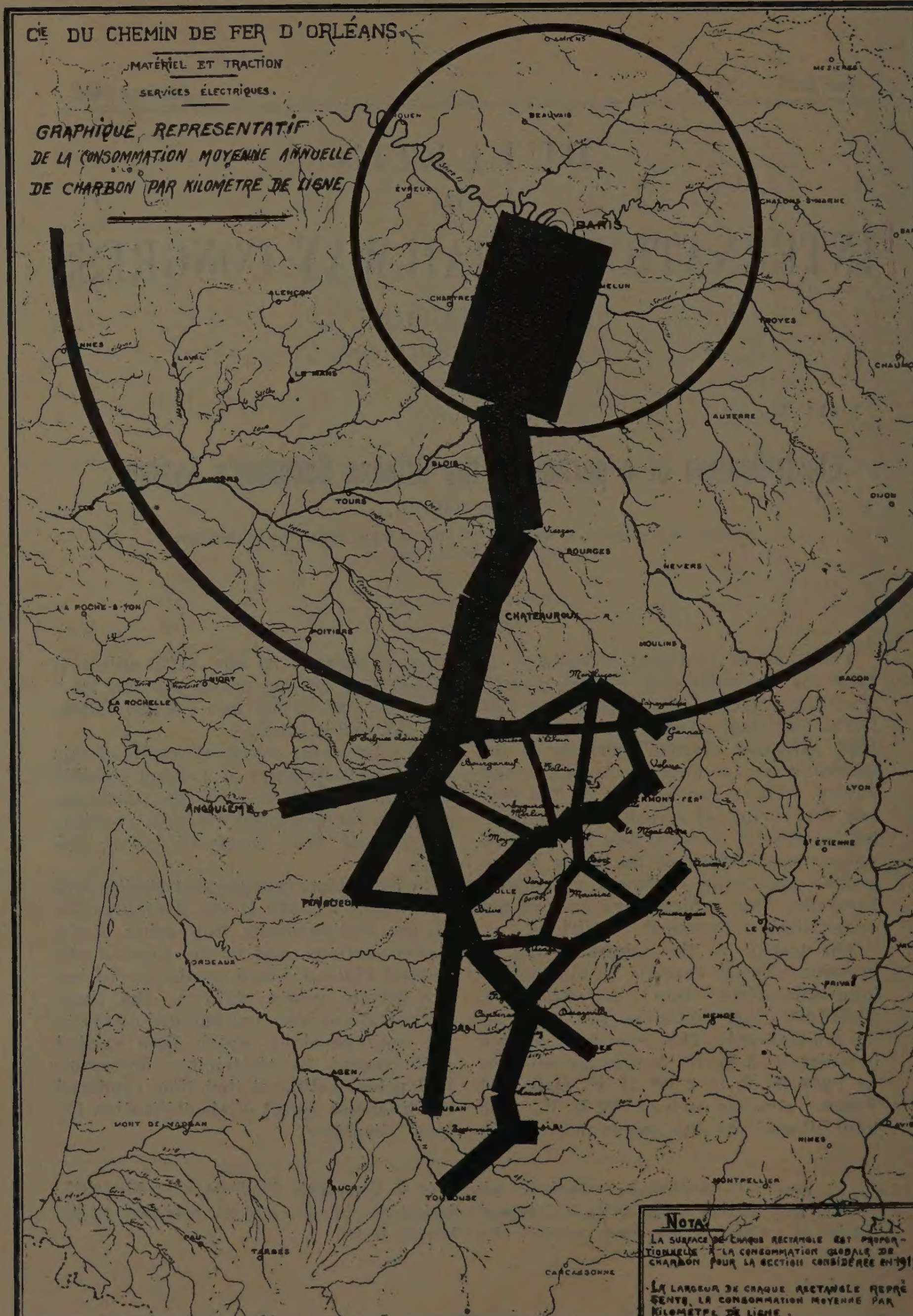
Cie DU CHEMIN DE FER D'ORLÉANS
MATÉRIEL ET TRACTION
SERVICES ÉLECTRIQUES.
GRAPHIQUE REPRESENTATIF DE LA CONSOMMATION MOYENNE ANNUELLE DE CHARBON PAR KILOMÈTRE DE LIGNE
NOTA:
LA SURFACE DE CHAQUE RECTANGLE EST PROPORTIONNELLE À LA CONSOMMATION GLOBALE DE CHARBON POUR LA SECTION CONSIDÉRÉE EN 1913
LA LARGEUR DE CHAQUE RECTANGLE REPRÉSENTE LA CONSOMMATION MOYENNE PAR KILOMÈTRE DE LIGNE.
AMIENS
BEAUVAIS
ROUEN
ÉVREUX
PARIS
CHALONS-S-MARNE
CHARTRES
MELUN
TROYES
ALENÇON
LAVAL
LE MANS
AUXERRE
BLOIS
ANGERS
TOURS
DIJON
BOURGES
NEVERS
CHATEAUROUX
POITIERS
MOULINS
NIORT
LA ROCHELLE
ANGOULÊME
LYON
PÉRIGUEUX
BORDEAUX
AGEN
MONT DE MARSAN
TOULOUSE
TARBES
CARCASSONNE
NIMES
MONTPELLIER
MENDE

Fig. 1.

Explanation of French terms in fig. 1 :

Left top corner : PARIS-ORLEANS RAILWAY COMPANY. ELECTRIC SERVICES. Chart representing the average annual coal consumption per kilometre of line.

Right bottom corner : NOTE. — The area of each rectangle is proportional to the whole consumption of fuel on the section considered, in 1913. The width of each rectangle represents the average consumption per kilometre of line.

About 1916 the investigation of the water falls of the Central Plateau was resumed and carried forward energetically in co-operation with the Government; the first scheme for the partial electrification of the Orleans lines was put forward in 1918. This scheme is the one referred to in most of the official statements published at the present time. It provided for the conversion to electric working of practically the whole of the lines in the neighbourhood of the falls of the Upper-Dordogne.

A more detailed study was undertaken in 1919 and the original scheme was completely revised. The underlying idea was to substitute for a partial and local electrification a scheme of a much more comprehensive nature which would have more far-reaching results than the mere conversion to electric working of a few steam-operated railway lines. It will, in fact, render directly possible the creation of one of the most important arteries of our national power transmission network, the one running from north to south between Paris and the Central Plateau.

Since energy can be transmitted electrically over great distances, the electrification of a railway system need not be limited to the lines in the vicinity of the generating stations; it follows that investigation should first be directed to ascertaining which lines can most advantageously be electrified, leaving for subsequent examination the question as to whether the situation of the steam or hydraulic power stations is so remote as to prove an insuperable obstacle to the electrification.

Whether considered from the railway-operating point of view or as a national question, it appears logical to replace steam by electric traction first of all on those lines which use the greatest quantity of coal per unit length of track equipped.

The map (fig. 1) of the Eastern section of the Orleans system gives a clear picture of this « density of consumption »; each line is represented by a rectangle whose area is proportional to the yearly fuel consumption, the height, therefore, being proportional to the average expenditure of coal per kilometre. It is at once apparent that for the same length of line equipped in the two cases, the Paris-Toulouse line will show a much greater saving of coal than the lines of the Central Plateau with their difficult gradients (1).

The mountain lines are not necessarily the more interesting ones from the electrification point of view and contour difficulties are only one factor in the problem.

Obviously the density of coal consumption gives only a general indication; to obtain a clear and complete picture it is necessary to compare the costs of operating by electric and steam traction in relation to both the *profile* and the *traffic*. Statistics to enable this to be done are lacking for both steam and electric traction, so that it is not yet possible to deal with this subject in an exact and detailed manner.

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(1) For purposes of comparison, two circles have been drawn to the same scale to represent — the larger circle, the coal consumption of the Paris district for purposes other than railways; and the smaller circle, the coal consumption of electricity works only in Paris and its suburbs.

Nevertheless, it is proposed to indicate briefly the general trend of the variation of operating expenses per tonne hauled as a function of the characteristic gradient and the traffic.

Net cost of steam and electric traction.

The net cost of operating a traction undertaking of any kind is always made up of two distinct factors corresponding to :

1 — the fixed charges, capital or otherwise, which can be considered as a first approximation, to be proportional to the length of the line under consideration.

2 — the operating expenses proper, such as, at a first approximation, can be considered proportional to the traffic on the line considered.

This is the same thing as saying that the average expenditure per kilometre of line would be of the form :

$$d = a + b\mathrm{T}$$

where T represents the average traffic per kilometre expressed, say, in tonne-kilometres hauled per kilometre. Messrs. Baume, Ricour, Amyot, Picard have shewn, from consideration of the general operating statistics for the railway systems, that this formula is very nearly correct (1); these writers found actually that the working expenses could be represented as a linear function of the receipts which in turn are practically proportional to the traffic.

Some other writers, Messrs. Baume, Noblemaire, Menche de Loynes, Jacquier, etc., have found, when studying the variation of working expenses from one line to another, and as between flat and hilly country, that the expenses d could be represented approximately by a hyperbolic curve.

The curves shewn in figure 2 represent, as a function of the characteristic gradient, the ratio of the working expenses of a kilometre of line of characteristic gradient i, to the corresponding expenses of a kilometre of practically level line (line for which the characteristic gradient is about 2.5 mm. per m. (1 in 400).

These graphs have been based on pre-war statistics of the French railway systems; a curve has been added which is based on the pre-war expenses of the Swiss railways.

All the curves are close to one another and do not differ much from the hyperbola having the equation

$$\mathrm{K} = \frac{52.5\,(1 + 0.04i)}{60 - i}$$

This hyperbola, as will be seen from figure 2 follows very closely the empiric curve corresponding to the figures of the Swiss Federal Railways (2).

As a first approximation, therefore, the surface representing the variation of total working expenses per kilometre of line may be represented, in the case of a steam line, by an expression of the form

$$d = (a + b\mathrm{T})\left(1 + \frac{\lambda + \mu i}{i_0 - i}\right)$$

where i_0 represents the limiting gradient.

There is not sufficient information available concerning electric working to permit an empirical formula to be deduced from the study of the operating statistics; but it is possible by a generalisation of the method of virtual lengths, as used by the Italian State Railways, and the method of imaginary tonnages used by the American railways, to demonstrate that the expression given above is valid with slight modifications as a first approximation in the case of any system of traction.

(1) These engineers have taken the receipts per kilometre of line as parameter, instead of the traffic in tonnes hauled.

(2) No line is absolutely level ($i = o$); we may assume that for a practically level line $i = 2.5$. The formula gives $\mathrm{K} = 1$ for $i = 2.5$ ‰ (1 in 400).

An explanation of this theory would be quite beyond the scope of the present note. We shall limit ourselves here to pointing out that for traction by pure adhesion an evaluation of the performance of an electric or steam engine considered as a « traction machine » necessitates the inclusion from the outset in the definition of useful tractive work expressed in virtual tonne-kilometres hauled, of an adhesion factor (ratio of the adhesive weight to the total weight of

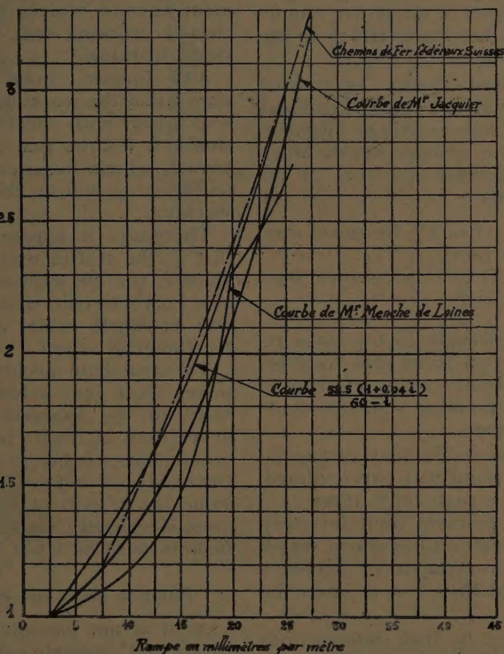


Fig. 2. — Curves showing the variation in net traction costs with steam traction, as a function of the gradient. (Value of the correction coefficient K).

Explanation of French terms: Chemins de fer Fédéraux suisses = Swiss Federal Railways. — Courbe de M^{r}...... = Mr. ......'s curve. — Rampe en millimètres par mètre = Rising gradient in millimetres per metre.

the train). For any particular line and train, the virtual tonne-kilometrage varies according to whether haulage is effected by a single locomotive or by motor-coaches distributed throughout the length of the train.

With electric traction it is possible to form motor-coach trains the whole weight of which is available for adhesion; this is the case on the Fayet-Chamonix line with a gradient of 60 mm. (1 in 17), and on the tramway system of Boulogne, Laon and elsewhere, on which the characteristic gradient amounts

to 115 mm. or even 122 mm. per metre (1 in 8.6 and in 8.2).

Thanks to regeneration it is always possible with electric traction to reduce the total consumption of energy by allowing locomotives descending a gradient to supply part of the power required for hauling other trains either on the level or on a slope.

The generalised theory of virtual lengths which enables a rational comparison to be made between single and multiple-unit traction systems draws attention to the important influence of the limiting gradients :

of about 60 $^0/_{00}$ (1 in 17) for steam traction,

— 140 $^0/_{00}$ (1 in 7) for electric traction.

We are thus brought to the same results, in a different form, that were set out briefly previously when referring to the studies of operating statistics made by various engineers.

Although these results may be incomplete and their proof was only outlined, they suffice to explain how there is a traffic limit or gradient limit for steep lines or heavy traffic lines above which limits electric working is of necessity more economical than can be given by steam operation.

Figure 3 shows by their intersections with the co-ordinate planes, $T = o$ and $i = o$, the surfaces which represent the cost of electric working and steam working as functions of the traffic density T (traffic in tkm. per km.) and of the characteristic gradient i.

For light traffic and a level line the costs per kilometre will necessarily be greater with electricity than with steam since the costs peculiar to electric working are the same as those for steam working, with the addition of the considerable financial charges due to the electrical equipment. Hence point E in figure 3 must be higher than point V.

Since the limiting gradient for which the working costs become prohibitive is much higher for electricity, 140 mm. (1 in 7), than that corresponding to steam locomotive traction, the surfaces must intersect and there will be a gradient beyond which, for equal traffic, electric working will be cheaper than steam working.

And further, since experience has shewn that the working expenses proper are lower with electricity than with steam, it follows that there is a traffic beyond which, for equal gradients, electric traction will be cheaper than steam working.

Therefore, it appears unquestionable that if the traffic exceeds a particular volume, the electrification of a line of any characteristic gradient whatsoever will be worth while considering from the financial aspect.

The economic problem therefore, resolves itself into determining for each value of the characteristic gradient a lower limit of traffic beyond which the balance turns in favour of electrification. Obviously in arriving at this balancing value the growth of traffic and the increased capacity resulting from electrification must be taken into account.

Balance sheet for electrification.

As it is not possible to make an accurate and complete calculation, we will try and establish a balance sheet for electrification by making certain simplified assumptions.

Let us attempt to evaluate the financial results of electrification by equating the following quantities :

For steam traction :

a) The expenditure on fuel;

b) The average saving in the depots and workshops on staff and maintenance and repairs of the rolling stock.

For electric traction :

a) The annual charges for interest and

amortisation, the cost of providing the fixed equipment (transmission lines, transforming stations and substations, overhead lines, etc.);

b) The cost of electric energy for exactly the same service as given under steam operation;

c) Staff and maintenance expenditure

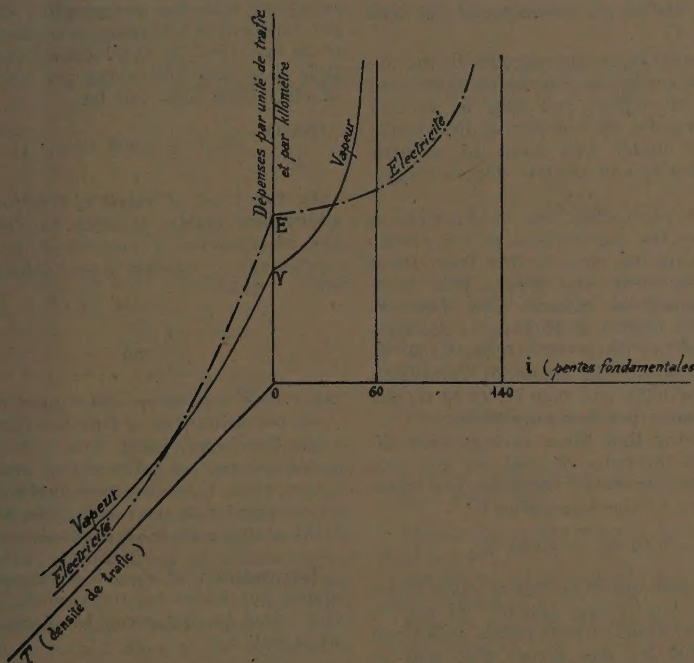


Fig. 3. — Typical curves of working costs per kilometre as a function of the traffic density and the characteristic gradient.

Explanation of French terms:

Dépenses par unité de trafic. etc. = Expenditure per unit of traffic and per kilometre. — Electricité = Electricity. — *i* (pentes fondamentales) = *i* (characteristic gradient). — *T* (densité de trafic) = *T* (traffic density). — Vapeur = Steam.

for substations; maintenance and repairs of the contact line.

We shall leave out of account the cost of purchasing the rolling stock, not only for the reason that the comparison is thereby simplified, but also because experience of electrifications already carried out shows that the expenditure called for by the electric rolling stock does not as a rule differ very much from that corresponding to the purchase of steam locomotives to maintain the same

service; this point will be referred to again in greater detail a little later.

If, therefore, we let Q stand for the fuel consumption expressed in tonnes per kilometre of line, and C for the price of a tonne of coal delivered to the tender, the cost of fuel per kilometre of line will be $Q \times C$.

The average saving effected in the depots and workshops on maintenance and repairs of engines can only be arrived at empirically by comparing the results obtained under this head in existing steam depots and electric depots respectively.

In the particular case of the Orleans Company the comparison of the results of working the electric line from Paris to Juvisy with the steam line from Luxembourg to Sceaux and Limours brings to light a saving per train-kilometre of the order of 1 franc (1.60 fr. per mile) under the economic conditions ruling in 1922, and 0.30 fr. (0.48 fr. per mile) under pre-war conditions.

Assuming that these savings vary directly as the price of coal, we can represent the economy obtained per train-kilometre by the expression :

$$0.10 \text{ fr.} + 0.009 \text{ C.}$$

This assumption is clearly open to argument, but if we restrict its use to small variations of coal prices above and below 100 fr., any errors that will be introduced will not affect the final result very greatly.

On heavy-gradient lines, where steam locomotives often work under unfavourable economic conditions, it will be necessary to make an addition of ε %, which may be taken as 25 % for gradients of the order of 15 mm. per metre (1 in 66) in accordance with the results obtained in operating the mountain lines of the Italian State Railways.

The saving effected per train-kilometre would thus be of the form.

$$(0.10 + 0.009 \text{ C}) \ (1 + \varepsilon).$$

As moreover, the number of train-kilometres is approximately equal to

$$\frac{1000 \text{ Q}}{28}$$

assuming that the consumption of coal per locomotive-kilometre is of the order of 28 kgr. (99.3 lb. per locomotive-mile), it is seen that the saving per kilometre of electrified line will be

$$\frac{1000 \text{ Q}}{28} \ (0.10 + 0.009 \text{ C}) \times (1 + \varepsilon).$$

In the case of electric traction, the additional yearly charges for interest and amortisation in respect of the fixed equipment — contact lines, substations, etc., — are :

$$\frac{Pr}{100}$$

wherein P represents the capital required per kilometre of line for installing the fixed equipment,

and r the rate of interest and amortisation plus 1 % to cover maintenance and repairs of the fixed material, also the staffing of the substations.

The quantity of electrical energy consumed per kilometre for running a service equal to that given by steam operation will be

$$\frac{1000 \text{ Q}}{\lambda}$$

wherein λ is the number of kilogrammes of coal which can be replaced by 1 kw.-hour delivered from the substations. The value of the coefficient λ depends upon the performance of the steam engines and the service conditions on the particular line; it appears to vary between 2.5 and 3.5 kgr. (5.5 and 7.7 lb.) according to tests carried out in the U. S. A. and France. For suburban trains we have found the figure to be nearer 4 (8.8 lb.) than 3.5 (7.7 lb.).

Finally, if p is the price at which energy is delivered to the substations, the cost of current is :

$$\frac{1000\,Q\,p}{\lambda}$$

The formula representing the balance sheet for electrification is, in accordance with the foregoing :

$$QC + \frac{1000}{28}\,Q\,(0.10 + 0.009\,C) \times (1 + \varepsilon) = \frac{1\,000\,Qp}{\lambda} + \frac{Pr}{100}$$

whence

$$Q = \frac{\frac{Pr}{100}}{C\,[1 + 0.32\,(1 + \varepsilon)] + 3.57\,(1 + \varepsilon) - \frac{1000\,p}{\lambda}}$$

For lines in level country for which $1 + \varepsilon = 1$, we have :

$$Q = \frac{\frac{Pr}{100}}{1\,32\,C + 3.57 - \frac{1000p}{\lambda}}$$

We will now apply these formulæ to the case of lines having easy gradients with 1, 2, 3 and 4 tracks and to single and double-track mountain lines. The various coefficients which appear in the formulæ will be based on values corresponding to the economic conditions existing in 1920, when the investigation was made. The results which we shall arrive at would have to be modified if it were desired to take into account the changes which have occurred since 1920, particularly those in connection with finance, but this very reason of the instability of currency makes it of little value to give figures other than those used at the time the scheme was worked out.

The values adopted in the calculations are :

Capital expenditure per kilometre (*per mile*) of line (P) :

800 000 fr. (*1 287 500 fr.*) for line with four tracks;

650 000 fr. (*1 460 050 fr.*) for line with three tracks;

470 000 fr. (*756 375 fr.*) for line with two tracks;

250 000 fr. (*402 325 fr.*) for line with one track.

	Lines in flat country.	Mountain lines.
λ	3	3.3
p	0.10 fr.	0.09 fr. (1)
r	8.5 %	8.5 %
ε	0 %	25 %

(1) The cost of current is less in the case of mountain lines since these are situated in the immediate vicinity of water falls and it is assumed that all the energy is furnished by hydro-electric stations.

Limiting coal consumption Q per kilometre of line.

	Lines in flat country.				Mountain lines.	
	$1+\epsilon=1$ $\lambda=3$		$r=8.5$	$p=0.10\,fr.$	$1+\epsilon=1.25$ $r=8.5$	$\lambda=3.3$ $p=0.09$
No. of tracks / Price of coal C	Four $Q=\dfrac{51\ 500}{C-22.6}$	Three $Q=\dfrac{41\ 800}{C-22.6}$	Two $Q=\dfrac{30\ 200}{C-22.6}$	One $Q=\dfrac{16\ 100}{C-22.6}$	Two $Q=\dfrac{28\ 500}{C-16.3}$	One $Q=\dfrac{15\ 150}{C-16.3}$
120...	530	430	310	165	275	146
110...	590	480	348	184	304	162
100..	665	540	390	207	340	181
90...	765	620	448	239	387	206
80...	900	730	527	281	448	238
70...	1 085	880	638	340	530	282
60...	1 380	1 120	808	430	652	347
50...	1 880	1 525	1 100	588	846	450

These figures are intended to serve only as a general guide, because in present economic conditions they are subject to wide variations such that the price of coal alone cannot be considered as a satisfactory index of the cost of electrification or the expense of working a steam or electric line.

The only deduction which it is hoped to draw from considerations as simple and general as these, is the order of magnitude of the « minimum traffic » which is essential for the financing of an electric conversion scheme to be profitable.

No account has been taken in our balance sheet of the income that will be derived by the French railways from the transmission and sale for industrial purposes of electrical energy produced in their power stations and transmitted along their lines. We have dealt solely with the problem of electrifying a section of a railway system, without complicating it by introducing other purely commercial considerations. In any given case it would be necessary to take into account the resources thus created if a complete balance sheet is desired. The choice of the direct-traction system in France has, indeed, been made with the object of facilitating the interconnection of the general distribution networks with those of the railways.

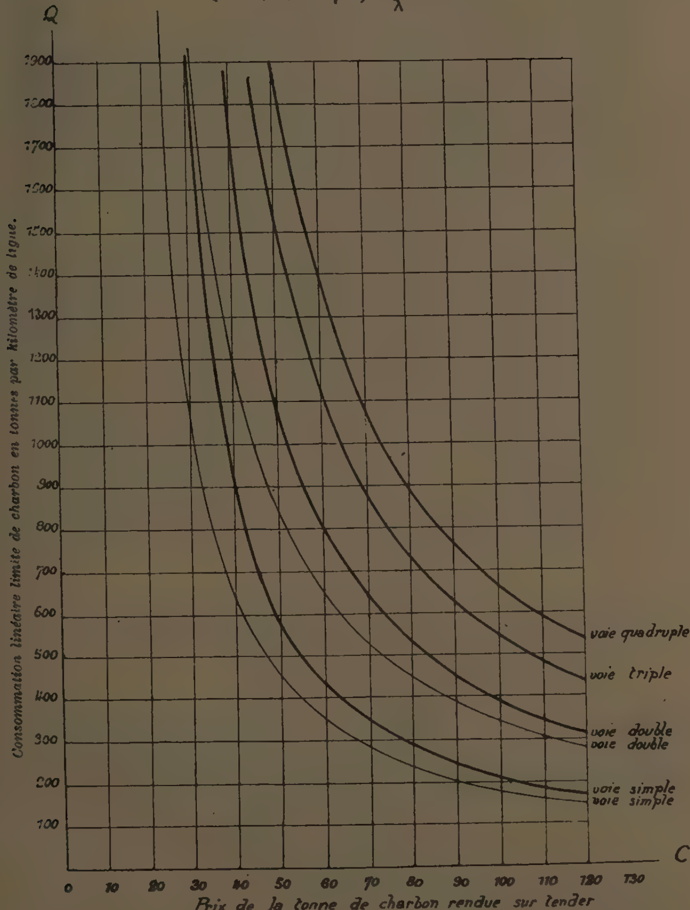
Such interconnection and the consequent pooling of their generating and transmitting facilities will have important economic results for all the undertakings concerned.

In figures 5 to 14 curves are reproduced showing the variation of traffic density from year to year on the various sections of the Orleans system which are in course of electrification; these curves give the traffic density in millions of tonne-kilometres (tkm.) per kilometre for the period of 1895 to 1923 inclusive. By comparing these curves with those in figure 4 it is a simple matter to ascertain the value of the limiting traffic (1).

(1) This comparison can be easily made by converting the traffic density in tkm. per km. into the coal-consumption density per km. of line, making use of the ideas of virtual length and virtual traffic (virtual tonne-kilometres).

As a first approximation it may be assumed that the coal consumption per virtual tonne-kilometre is of the order of 60 grammes (0.2 lb. per virtual English ton-mile).

$$Q = \frac{\frac{Pr}{100}}{C\left(1+0{,}32(r+\varepsilon)\right)+3{,}57(r+\varepsilon)-\frac{1000\,P}{\lambda}}$$



Légende { —— lignes plates / — lignes de montagnes

Fig. 4. — Curves connecting the limiting coal consumption per kilometre of line, Q with the price of fuel per ton, C.

Explanation of French terms:

Consommation linéaire... = Limiting consumption of coal in metric tons per kilometre of line. — Légende etc. = Note : —— Flat lines. — Mountain lines. — Prix de la tonne de charbon... = Price of coal per tonne on tender. - Voie simple... double... triple... quadruple = Single track... double track... 3-track... 4-track line.

Figs. 5 to 14. — Curves of variation of annual traffic, passengers and goods.

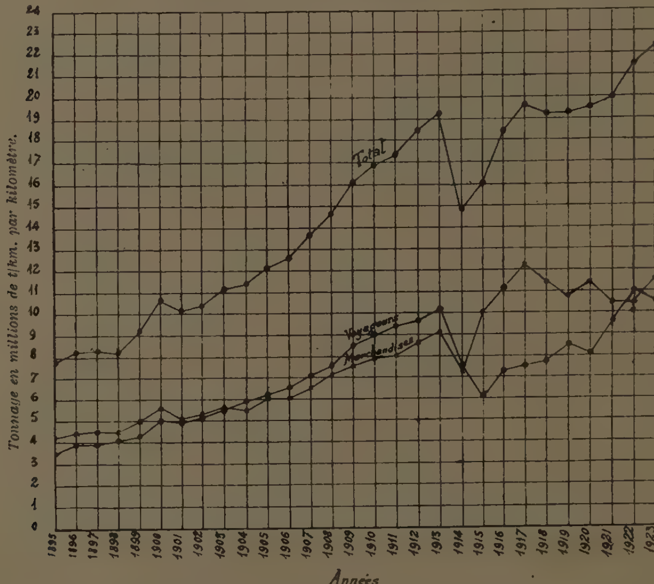


Fig. 5. — Paris-Orleans. L = 125 km. (77.7 miles).
Four tracks from Paris to Etampes — double line from Etampes to Orleans.

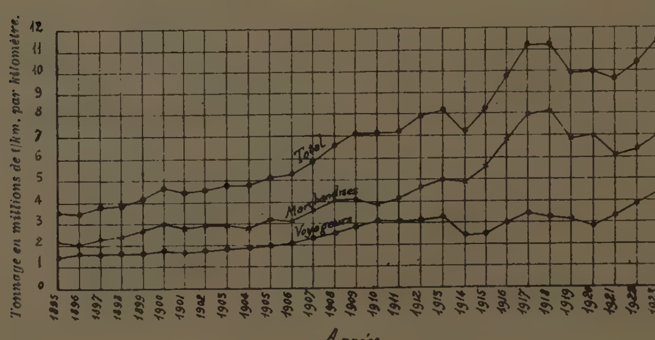


Fig. 6. — Orleans-Vierzon. L = 82 km. (51 miles) — double line.

Figs. 5 to 14 (*continued*). — Curves of variation of annual traffic, passengers and goods.

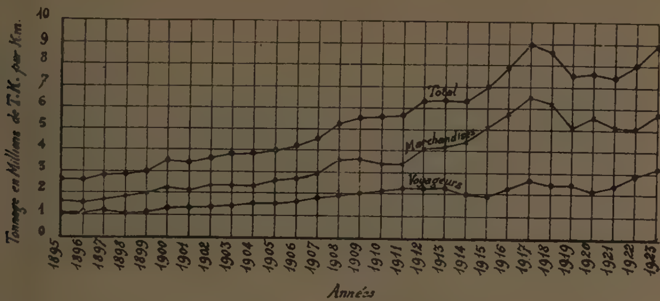


Fig. 7. — Vierzon-Châteauroux. L = 63 km. (39.1 miles) — double line.

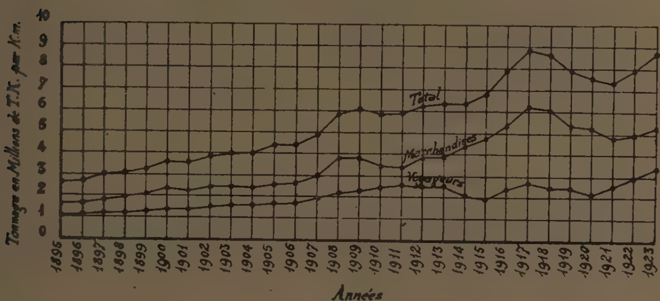


Fig. 8. — Châteauroux-Limoges. L = 137 km. (85.1 miles) — double line.

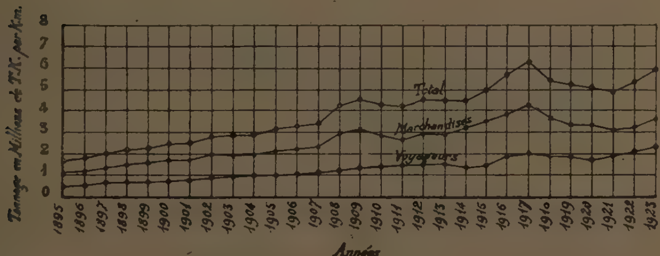


Fig. 9. — Limoges-Brive. L = 99 km. (61.5 miles) — double line.

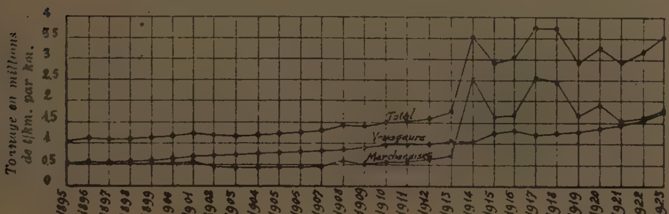


Fig. 10. — Brétigny-Tours. L = 214 km. (133 miles) — double line.

Figs. 5 to 14 (*continued*). — Curves of variation of annual traffic, passengers and goods.

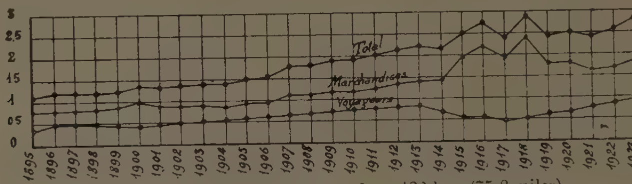


Fig. 11. — St-Sulpice-Montluçon. L = 122 km. (75.8 miles).

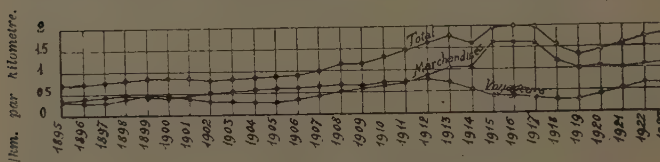


Fig. 12. — Brive-Tulle. L = 26 km. (16.2 miles).

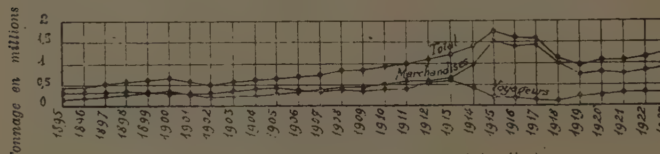


Fig. 13. — Tulle-Ussel. L = 66 km. (41 miles).

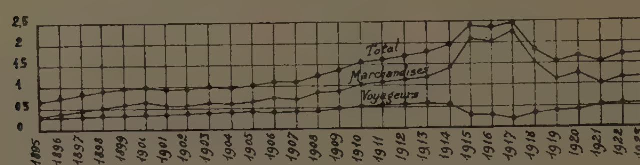


Fig. 14. — Ussel-Clermont. L = 106 km. (65.9 miles).

Explanation of French terms in figs. 5 to 14 :

Années = Years. — Marchandises = Goods. — Tonnage en millions.... = Tonnage in millions of tonne-kilometres per kilometre. — Voyageurs = Passengers.

For a line in flat country, such as the Paris-Brive line of three tracks, which had a mean coal consumption of about 700 tonnes per km. (1 109 Engl. tons per mile) in 1913, it is apparent that electrification is largely justified at the present price of coal. But if account is taken of the fact that on a comparable line the pre-war traffic was increasing at the rate of about 3.5 % per annum, it seems evident that when electrification is complete and the substations are fully utilised, electric working will still be profitable with fuel at a price in the region of 60 francs. This is all the more interesting because the annual rate of increase of traffic has shewn a marked upward tendency in the last few years, especially on the section Vierzon-Brive where it has reached nearly 10 %.

For single track mountain lines such as those of Brive-Clermont and St. Sulpice-Montluçon on which the density of coal consumption reaches 240 and 200 tonnes (379 and 317 Engl. tons) respectively, it can be seen that the conversion from steam to electric working is justified by the present traffic; if the increase of traffic capacity that will result from electrification is taken into account the conversion will show to still greater advantage.

Special studies of lines included in the first stage of the electrification of the Orleans system.

A traction service is determined when the profile of the line, the time schedule and the weight of the trains are known. As the weight of the trains varies with the traffic carried, the maximum permissible weight can be defined accurately only in relation to the particular system of working that is adopted; in the case of lines hitherto operated by steam trains, the maximum train weight can be taken, as a first approximation, as that corresponding to the loading schedules of the steam locomotives for the *minimum* nominal speeds actually realised (1).

The maximum number of trains provided by the time table (including optional trains) and the maximum weight of each train, determine a total traffic in actual tonne-kilometres, which we shall refer to as the *maximum* traffic. It is on the basis of this maximum traffic that the whole of the fixed equipment and rolling stock have been calculated for all the lines comprised in the first stage of the electrification of the Orleans Railway Company.

Figure 15 shows for each of the lines, Paris-Brive, Brétigny-Dourdan, St. Sulpice-Gannat, Brive-Clermont, the principal characteristics of the traction service, *viz.:* the profiles, on which are marked the positions of the substations and the virtual distance between substations for both directions of running, the number of trains run on the various sections, etc.

For the section Paris-Vierzon which is now being electrified, the 1914 time tables correspond to the maximum electric traffic given in the following table, expressed in millions of tonne-kilometres

	Total tkm. in millions. (Total *English ton-miles in millions*			Density of traffic. Total tkm. per km. (Total *Engl ton-miles per mile*), in millions.	Tkm. (*English ton-miles*) hauled, in millions.			Traffic in millions of tkm. hauled per km. (*of Engl. ton-miles hauled per mile*).
	Passenger.	Goods.	Total.		Passenger.	Goods.	Total.	
Quai d'Orsay. (125 km. = 77.7 miles).	3 091 (1890)	2 706 (1 655)	5 807 3 551	46.5 (45.76)	2 683 (1 641)	2 420 (1 480)	5 103 (3 121)	41 (40.35)
Les Aubrais . (80 km. = 50 miles) Vierzon	772 (472)	1 073 (656)	1 845 1 128	23 (22.63)	653 (399)	982 (600)	1 635 (1 000)	20.5 (20.18)
Brétigny..... (24 km. 2 = 15 miles) Dourdan.. ..	139 (85)	165 (101)	304 186	12 5 (12.30)	128 (78.2)	152 (93)	280 (171)	11.6 (11.41)

(1) In order to obtain the maximum sustained tractive effort, as will be shwen in detail later in this note.

(tkm.) hauled and total millions of tkm. per annum (1).

If we compare the traffics shewn in this table with the curves of variation of traffic given on pages 12 to 14 it is seen that they are about double those of 1923, which reached the following figures :

22.0 10^6 tkm. hauled per km. on the section Paris-Orleans;

11.7 10^6 tkm. hauled per km. on the section Orleans-Vierzon;

3.5 10^6 tkm. hauled per km. on the section Brétigny-Dourdan.

As all the calculations of average and maximum loads on the substations were made on the basis of the maximum traffic in question, it is clear that at the normal rate of increase of traffic (2), the designed layout will meet the require-

(1) These calculations were made on the basis of the following maximum train weights for the section in question.

Type of train.	Tonnage hauled.	Locomotive.	Total.	Type of train.	Tonnage hauled.	Locomotive.	Total.
	Metric (English tons).				Metric (English tons).		
Fast (rapide). . . .	530 (522)	112 (110)	642 (632)	Market produce. . .	500 (492)	65 (64)	565 (556)
Express	650 (640)	112 (110)	762 (750)	Goods	1 000 (984)	65 (64)	1 065 (1 048)
Through	350 (344)	65 (64)	415 (408)	Goods (wagon) . . .	1 100 (1 082)	130 (128)	1 230 (1 210)
Light	295 (290)	65 (64)	360 (354)	Empty goods	400 (394)	65 (64)	465 (458)
Motor (2 units) . . .	—	—	296 (291)	Light engine (passenger)	—	112 (110)	112 (110)
Motor (3 units) . . .	—	—	444 (437)	Light engine (goods) .	—	65 (64)	65 (64)

(2) The average rates of increase of traffic per annum for the period 1903-1913 are given in the following table in train-kilometres and tonne-kilometres.

Section.	Train-kilometres.			Tonne-kilometres.		
	Passengers.	Goods.	Average.	Passengers.	Goods.	Average.
Paris-Orleans	3.56 °/o	0.41 °/o	2.70 °/o	6.3 °/o	4.93 °/o	5.63 °/o
Brétigny-Vendôme.	3.34	4.03	3.49	3.78	5.26	4.35
Orleans-Vierzon	2.69	0.35	1.58	5.8	5.16	5.27
Vierzon-Châteauroux	3.96	4.90	4.34	5.48	5.69	5.61
Châteauroux-Limoges.	2.91	2.74	2.84	5.59	4.85	5.11
Limoges-Brive	3.80	0.35	1 90	5.50	4.18	4.61
Brive-Tulle	2.53	8.72	3.90	3.24	13.73	8.11
Tulle-Ussel	0.82	8.75	3 94	5.33	11.11	7.95
Ussel-Clermont	1.82	3.73	2.86	4.97	6.57	6
St-Sulpice-Montluçon.	3.94	0.23	2.29	5.84	4.62	5.06

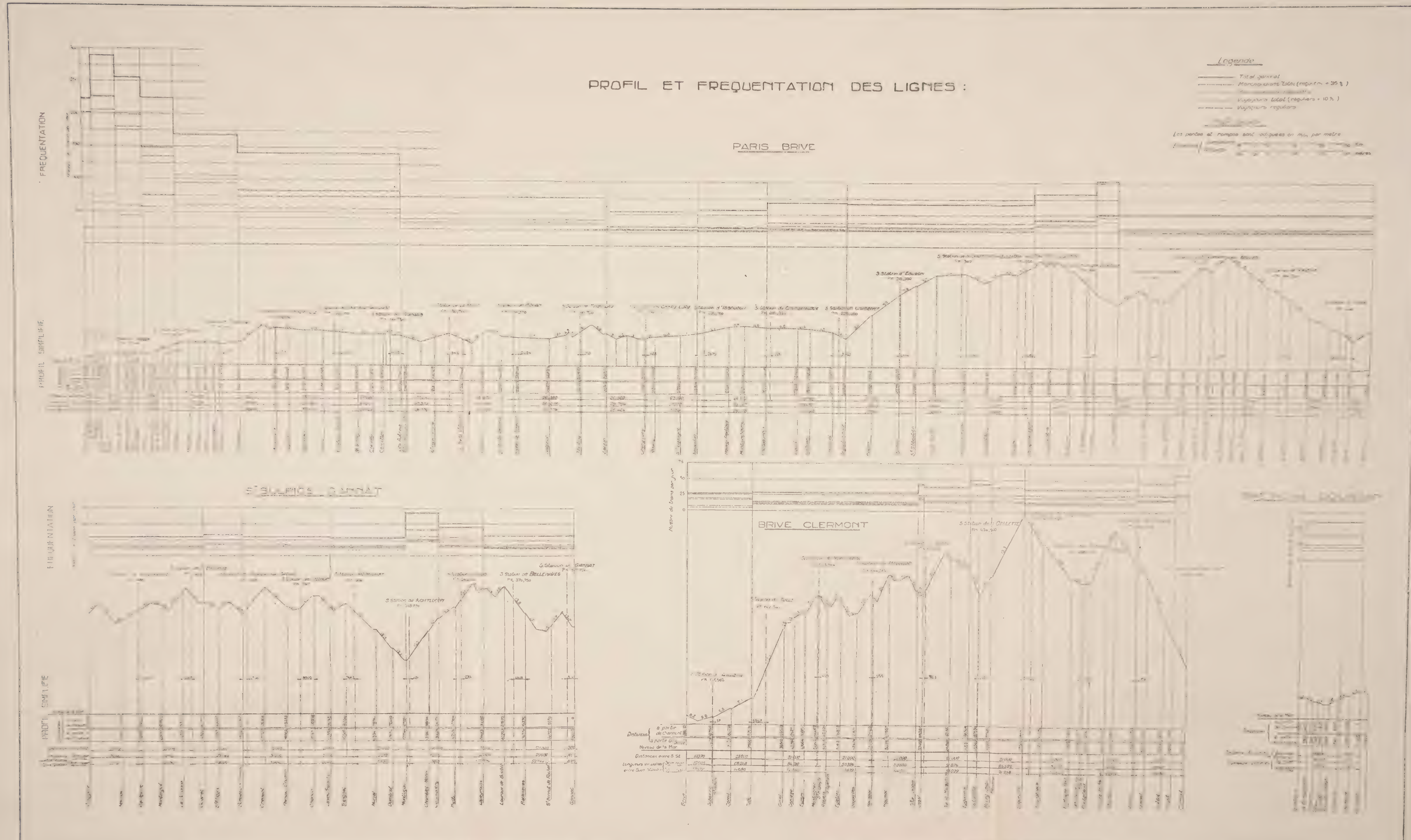


Fig. 15.

Explanation of French terms :

Altitudes = Heights. — Distances à partir de ..... = Distances from ..... — Échelles = Scales. — Fréquentation = Density. — Les pentes et rampes sont indiquées en mm. par mètre = Gradients given in mm. per metre. — Longueurs = Lengths. — Longueurs virtuelles = Virtual lengths. — Marchandises réguliers = Booked goods. — Marchandises total (réguliers + 35 %) = Total goods (booked + 35 %). — Niveau de la mer = Sea level. — Nombre de trains par jour = Number of trains daily. — Profil et fréquentation des lignes = Gradient section and train density of the lines. — Profil simplifié = Simplified gradient section. — Total général = General total. — Voyageurs réguliers = Booked passengers. — Voyageurs total (réguliers + 10 %) = Total passengers (booked + 10 %).

ments of at least five years or so, assuming that additional machines are put down as required on the positions reserved for them.

The following table gives the plant capacity provided for and actually installed in each substation, as well as the approximate average and maximum loads calculated on the basis of the maximum traffic. Figures 16 and 17 show the variations of the traffic load in the different substations corresponding to this maximum traffic, the loads having been calculated at quarter-hour intervals.

Names of substations.	Maximum traffic.		Nominal capacity.	
	Average calculated load, approx.	Calculated peak, approx.	Eventual.	Installed.
Paris	[illegible] 500	18 000	8 000	6 000
Ablon	[illegible] 000	15 000	8 000	6 000
Saint-Michel	6 000	14 000	8 000	6 000
Etréchy	4 500	9 000	8 000	6 000
Monnerville	3 500	6 500	6 000	4 000
Château-Gaillard	3 500	6 000	6 000	4 000
Les Aubrais	3 500	12 000	8 000	6 000
La Ferté	2 300	6 000	6 000	4 000
Nouan-Salbris	2 300	6 000	6 000	4 000
Theillay	2 300	6 000	6 000	4 000
Saint-Chéron	1 600	6 000	6 000	4 000
			76 000	54 000

It is probable that under actual traffic conditions 32 000 kw. of running plant will be more than sufficient and that the average load factor of the substations will be of the order of 35 %.

As will be shewn in detail later, under the operating conditions corresponding to maximum traffic the percentage voltage variation at the d. c. busbars of the substations will not ordinarily exceed by more than 3 % the permissible voltage variation at the power station busbars when all the projected lines are working.

Under the present running conditions the normal voltage variation will be much smaller, although of course heavy momentary overloads will cause the voltage to fall automatically.

General description of the electrication scheme for the Paris-Brive line.

I. — Electric power supply.

Power will be generated as three-phase 50-cycle alternating current in a group of power stations, which, at present comprises :

1. The thermal stations of the Union d'Electricité Company, more particularly those at Genevilliers and Vitry.

2. The Eguzon hydro-electric station of the Union Hydro-électrique Company, established in association with the Orleans Company.

3. The hydro-electric stations of the Upper Dordogne, more especially those

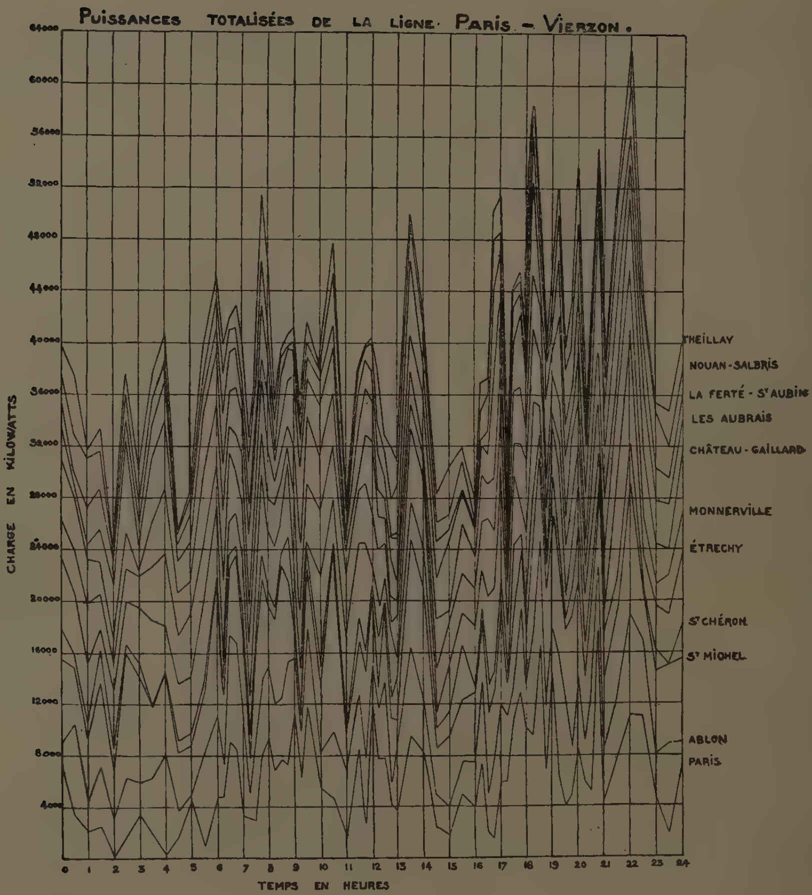


Fig. 16.

Explanation of French terms (figs. 16 and 17):

Charge en kilowatts = Load in kilowatts. — Puissances totalisées etc... = Totalised power on the Paris-Vierzon line. Temps en heures. — Time in hours.

at Coindre, Chavanon and Marèges operated by the Orleans Company under a concession.

The last-named stations will be interlinked with the Alpine stations which are already connected to the system of the Loire et Centre Company and energy will be interchanged as required.

PUISSANCES TOTALISEES DE LA LIGNE VIERZON PARIS

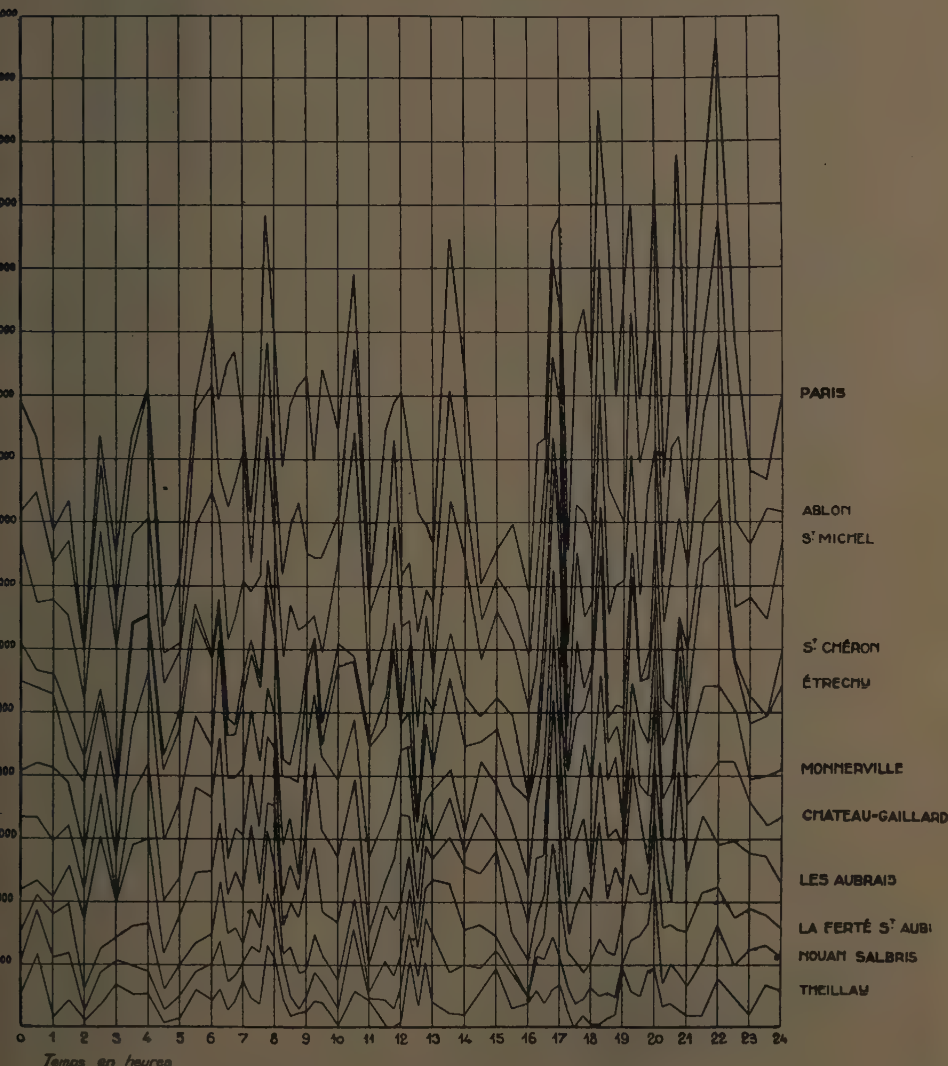


Fig. 17.

The operation of the entire group of power stations will be controlled by a central organisation on the « load-despatching » system. This power will be made available as follows :

At 13 500 volts, at the low-tension busbars of the Vitry station of the Union d'Electricité Company for the purpose of feeding traction substations at Paris and Ablon.

These busbars will be fed from 80 000 kw. of alternators in Vitry power station and by 70 000 kw. of transformers operating at 60/13.5 kilovolts (kv.).

During periods of heavy load the busbar voltage will be maintained at 13 500 and during times of light traffic at 12 850 with a permissible variation in both cases of 2 1/2 %.

At 60 kv., at the high-tension bars of the Union d'Electricité Company's substations at Vitry and Billancourt, this supply being delivered by that Company either from the Vitry or Genevilliers power stations.

The voltage will be maintained, within 2 1/2 %, at 60 kv. and 57.5 kv. during the busy hours and times of light load respectively.

At 90 kv., at the high-tension busbars of the power stations at Coindre, la Cellette and Vernéjoux.

II. — Power transmission.

The supply of electricity furnished by the various hydro-electric and thermal power stations named above will be transmitted as follows :

At 13.5 kv., by means of three 3-core 150-mm² (0.2635-sq. inch) cables from the 13.5-kv. busbars at Vitry power station to the Paris substations, the continuous capacity of each of these substations being 6 000/8 000 kw.

At 60 kv., by two groups of three single-core 150-mm² (0.2635-sq. inch) cables operating at 35 kv. between line and earth, which will connect the Vitry power house with the Chevilly transformer station.

At 60 kv., by one group of three single-core 150-mm² (0.2635-sq. inch) cables operating at 35 kv. between line and earth, which will connect the Billancourt substation with the Chevilly transformer station.

At 90 kv., by two three-phase overhead lines of 238 mm² (0.3689-sq. inch) section (steel-cored aluminium) which will connect the 90-kv. busbars at Eguzon power-house with 90-kv. busbars at the Chevilly transformer station by way of the 15 traction substations on the route from Paris to Eguzon : St. Michel, St. Chéron, Monnerville, Château-Gaillard, Les Aubrais, la Ferté-St. Aubin, Nouan, Theillay, Cherry-Lury, Issoudun, Châteauroux, Chabenet. These lines will be extended as far as Souillaç to feed the 7 substations at Eguzon, La Souterraine, St. Sulpice-Laurière, Les Bardys, Solignac, St. Germain-les-Belles, Vigeois, Ussac; they will then connect up to the 90-kv. transmission systems coming from the power stations of the Central Plateau which practically follow the course of the railways from Montluçon to St. Sulpice-Laurière, Montluçon to Eygurande, and Brive to Clermont.

At 150 kv. (increased to 220 kv. later) by an overhead line, capable of being duplicated at some future date, which links the transforming stations at Chevilly, Chaingy, Eguzon and Marèges.

Figure 18 is a diagram of the general distribution system and shows clearly the various interlinks which are or will be established between the several sources of power and the principal centres where that power will be utilised.

The interconnection of the Orleans Company's power houses in the Central Plateau with those of the Loire et Centre Company will be made by a 120-kv. line, which will follow generally the course of the projected line from Commentry to

GENNEVILLIERS
CHEVILLY
VITRY
PARIS 0 600
ABLON 13.600
ST MICHEL 29.967
ETRECHY 47.419
CHÉRON
MONNERVILLE 69 440
CHATEAU GAILLARD
LES AUBRAIS 114.780
HAINGY
LA FERTÉ 135.700
NOUAN 164.370
THÉOLAY (VIERZON) 190 750
CHÉRY-LURY
ISSOUDUN 239 700
CHÂTEAUROUX 265.965
CHABENET 292 650
ÉGUZON 315 960
EGUZON
LA SOUTERRAINE. 340
SAINT SULPICE LAURIÈRE 365
LES BARDYS 390
SOLIGNAC 414
ST GERMAIN LES BELLES 439
VIGEOIS 464.500
USSAC 490
TULLE
SOUILLAC
MAREGES
COINDRE
3 x 9550 KVA
LA CELLETTE.
5 x 11000 KVA
2 x 16 500
+ 1 EVENTUEL
SAINCAIZE
COMMENTRY
ST GERMAIN-LES-FOSSÉS.
CLERMONT-FERRAND
KEY :
Power station.
Synchronous compensating set.
Substation.
Transformer.
LÉGENDE
USINE
COMPENSATEUR SYNCHRONE
SOUS-STATION
TRANSFORMATEUR
LIGNES 150 000 VOLTS
LIGNES 120 000 VOLTS
LIGNES 90 000 VOLTS
LIGNES 60 000 VOLTS
LIGNES 15800 VOLTS

Fig. 18.

St. Germain-des-Fossés (new section of the Bordeaux-Lyons line).

III. — Transforming and converting substations.

a) *Substations containing static transformers and synchronous regulating sets.*

The transmission lines at 60, 90, 120 and 150/220 kv. will be interconnected by five transforming stations located at Chevilly, Chaingy, Eguzon, Vernéjoux and Commentry.

Chevilly. — This station will connect the 150/220 kv. lines from Chaingy with the two 90-kv. lines forming the traction substation feeder network, and also with the 60-kv. cables from Vitry and Gennevilliers. It will contain :

1 bank of 150/60-kv. transformers having a capacity of 25 000 kva.

2 banks of 90/60-kv. transformers each bank having a capacity of 25 000 kva.

The 150/60 kv. transformers will be capable of acting either as step-down transformers for transferring energy produced in the power station at Eguzon or in those of the Central Plateau, in the direction Chaingy-Chevilly or, as step-up transformers for transferring energy from the power stations of the Union d'Electricité Company in the opposite direction.

The Chevilly transforming station has been planned with the idea of eventually bringing into it three additional 150/220-kv. lines with the installation of transformers of corresponding capacity.

Chaingy. — This station will connect the 150/220-kv. network with the 90-kv. traction substation feeder system and will also undertake the voltage regulation of the traction system. It will contain :

2 banks of 150/90-kv. transformers each having a capacity of 20 000 kva. one of which will act as a standby.

These transformers will have three windings, a 150-kv. primary, 90-kv. secondary, and a tertiary winding operating at 6 000 volts. The latter will supply synchronous compensating sets for regulating purposes, each of which will be of 10 000-kva. capacity.

Two 10 000-kva. synchronous regulating sets are adequate for voltage regulation purposes, but space has been provided for the installation of a third unit at some later date.

This station has been designed as an automatic sectionalising station for the 150-kv. and 90-kv. lines; it is intended to receive subsequently two additional 90-kv. lines running to Tours and to deal with 7 additional outgoing 150/220-kv. lines: 3 to Paris, 1 to Eguzon, 2 to Montluçon, 1 to Tours.

Eguzon. — This station will link the 150-kv. and 90-kv. networks of the Orleans Company with the Eguzon power station by means of intermediate 10 000-volt busbars. It will contain :

1 bank of 150/10-kv. transformers of 21 000 kva. capacity.

2 banks of 90/10-kv. transformers, each bank having a capacity of 24 000 kva.

Commentry. — This station will connect the 90-kv. networks of the Orleans Company to the 120-kv. network of the Transports Electriques du Centre Company, and to the 30-kv. system of the Loire et Centre Company. Its principal equipment will be :

1 bank of 120/90-kv. transformers of 25 000 kva. capacity;

2 banks of 120/30-kv. transformers, each bank of 15 000 kva. capacity.

This station will be established jointly by the Orleans Company and the Loire et Centre Company.

Marèges. — This station will form the collecting point for the power delivered at 90-kv. by the various powers stations operated by the Orleans Company, and which has to be transformed from 90 kv. to 150/220 kv.; each of these power stations has, in addition, to supply power at 90-kv. directly to the traction substations on the lines in the vicinity.

b) *Rotary convertor substations.*

In the 22 traction substations previously enumerated, the 3-phase, 50-cycle, supply at 13.5 kv. or 90 kv. will be converted into 1 500-volt direct-current.

Each of the 11 substations for the sections Paris-Vierzon (200 km. = 124.3 miles) and Bretigny-Dourdan (24 km. = 14.9 miles) will contain a number of sets, each of which consists of two 750-volt six-phase rotary convertors connected two in series.

The allocation of these converting units to the various substations is given in the following table :

Name of substation.	Feeder voltage, kv.	Installed capacity, kw. (continuous rating).	Capacity in service, kw. (continuous rating).	Maximum permissible peak output, kw.
Paris	13.5	3 × 2 000 = 6 000	4 000	12 000
Ablon.	13.5	3 × 2 000 = 6 000	4 000	12 000
St-Michel.	90	3 × 2 000 = 6 000	4 000	12 000
Etrechy	90	3 × 2 000 = 6 000	2 000	12 000
Monnerville.	90	2 × 2 000 = 4 000	2 000	6 000
Château-Gaillard	90	2 × 2 000 = 4 000	4 000	6 000
Les Aubrais	90	3 × 2 000 = 6 000	2 000	12 000
La Ferté.	90	2 × 2 000 = 4 000	2 000	6 000
Nouan	90	2 × 2 000 = 4 000	2 000	6 000
Theillay	90	2 × 2 000 = 4 000	2 000	6 000
St-Chéron	90	2 × 2 000 = 4 000	2 000	6 000
		27 × 2 000 = 54 000	32 000	

The total capacity that will be normally in service will be about 32 000 kw. or say 135 kw. per kilometre (217.2 kw. per mile).

IV. — Distribution system.

Power will be distributed throughout the whole extent of the electrified lines by means of contact lines of the overhead double catenary suspension type with double contact wires; in some sections with four tracks (Paris-Brétigny) by two third rails, used also as feeders, running along the centre roads.

Along the line from Brétigny to Brive will be installed sectional feeders adapted to the density of the traffic.

V. — Traction equipment.

There will be three different types of traction equipment; motor-coaches, medium-speed locomotives, and express locomotives.

The rolling stock now in service or under construction comprises :

For suburban and interurban passenger services, 80 motor-coaches, of about 63 t. (62 Engl. tons) weight and 20 m. (65 ft. 7 3/8 in.) in length, with a one-hour rating of 1 000 H. P. and continuous rating of 800 H. P.

For main line goods and passenger services (express and stopping trains), 200 locomotives of about 70 to 76 t. (69 to 75 Engl. tons) weight, type BB, with

two motor bogies each equipped with two motors and having a total one-hour rating of 1 500 H. P. (1 400 to 1 700 H. P. according to the particular class) and a continuous rating of 1 200 H. P. (1 200 to 1 540 H. P. according to the particular class).

For fast passenger services, market trains, etc., the type of locomotive has not yet been settled and systematic tests are to be undertaken with 5 trial machines, as follows :

1 type 2C + C2 locomotive equipped with gearless motors of 3 000 H. P. at the one-hour rating, and 2 200 H. P. continuous rating.

2 type 2D2 locomotives with connecting rod drive and a one-hour rating of 4 100 H. P. and continuous rating of 3 500 H. P.; one will have « hyperstatic » connecting rods and ordinary motors, the other « isostatic » connecting rods and fully compensated motors.

2 type 2D2 locomotives driven by outside gear-drive and small connecting rods, and having a one-hour rating of 3 700 H. P. and continuous rating of 3 300 H. P.; one with standard running gear and ordinary motors, the other with adjustable articulated running gear and fully compensated motors.

APPENDIX.

By means of a generalisation of the method of virtual lengths as used by the Italian Railways and the method of estimated tonnages employed in America, it is possible to give a rational proof of the conclusions arrived at from a study of the statistical information.

The virtual length of a line of actual length S is defined as the length L of level and straight line which would necessitate the same expenditure of mechanical energy to traverse it, as is expended in traversing the actual line. On this basis, the traffic on any line expressed in virtual tonne-kilometres corresponds to the same consumption of energy as the traffic in tonne-kilometres on the actual line. The coal consumption per virtual tonne-kilometre must then be practically the same on all lines, whatever their profile, if it is assumed that the average efficiency of locomotives in converting energy from one form to another is practically the same, irrespective of the line that is operated. Hence, on this hypothesis the idea of virtual length enables us to predetermine the coal consumption of any given line. Experience shows that the degree of approximation thus obtained is apparently of the order of 10 %.

The consumption of energy by a train running on a line of given profile may be calculated with any desired degree of accuracy if we know the laws of variation with speed of the tractive effort and the resistance due to the air and rolling.

For this purpose the following equations are made use of :

$$\mathrm{I} \left\{ \begin{array}{ll} (1) & M' \dfrac{dv}{dt} = F_1(v) - F_2(v) - F_3(S), \\ (2) & v = \dfrac{ds}{dt}, \\ (3) & v\,F_1(v) = \dfrac{dE}{dt}. \end{array} \right.$$

in which :

M' represents the apparent mass of the train calculated with due regard to the inertia of the rotating parts;

v the speed;

S the distance;

E the energy;

F_1 (v) the tractive effort;

F_2 (v) the rolling resistance;

F_3 (S) the local resistance due to gradients or curves.

By eliminating $F_1(v)$ between equations (1) and (3) we obtain

$$M' v \frac{dv}{dt} = \frac{dE}{dt} - v F_2(v) - v F_3(S)$$

or

$$E = \frac{1}{2} M' v^2 + \int_0^t \left[F_2(v) + F_3(s)\right] v \, dt = \frac{1}{2} M' v^2 + \int_0^S R(v, S) \, ds.$$

The virtual length L being defined by the relation

$$E = \frac{1}{2} M' v_1^2 + \int_0^L R(v) \, dS$$

(where R (v) is the resistance due to air and rolling on a level and straight track), the following relation should hold good :

$$\frac{1}{2} M' v^2 + \int_0^S R(v, S) \, ds = \frac{1}{2} M' v_1^2 + \int_0^L R(v) \, dS.$$

If r is a mean value of the resistance such that

$$\int_0^S R(v) \, ds = rL,$$

we can write

(4) $$\frac{1}{2} M' v^2 + \int^S R(v, S) \, ds = \frac{1}{2} M' v_1^2 + rL.$$

This equation (4) gives the virtual length L in accordance with te definition given earlier. It should be noted that by this definition the virtual length is made dependent not only on the profile of the line, but also on the composition and speed of the trains, the number of stops, the temperature, wind, etc. In order that the virtual length mav be defined geometrically by the profile of the line alone, it is necessary to make certain simplifying hypotheses which are in fact the basis of the method known as of virtual lengths.

We assume :

1. That the resistance r is the same on all lines;

2. That the function R (v, S) depends solely on the distance S and that it becomes r on a level and straight track;

3. That the speeds v and v_1 are equal.

Equation (4) then becomes

(5) $$\int_0^S R(S) \, dS = rL.$$

The calculation of L, the virtual length, is thus reduced to solving the integral $\int_0^S R(S) \, ds$ which can easily be effected by noting that

$$\int_0^S R(S) \, ds = -E_p + E_r + E_c + rS$$

where :

E_p = work done by gravity during descent of gradient;
E_r = work done against gravity during ascent of gradient;
E_c = work done in traversing curves.

From this we finally deduce :

$$L = S + \frac{-E_p + E_r + E_c}{r} \qquad (6)$$

This formula defines a theoretical virtual length which does not take into account the conditions under which electric and steam locomotives work in practice. If we try and give exact values to E_p, E_r, E_c, we are led to consider three kinds of virtual lengths corresponding to the three following cases :

1. Steam traction;
2. Electric traction without regeneration;
3. Electric traction with regeneration.

We can then write down three pairs of equations, distinguishing the ascent or descent of gradients by indices i and j, and those gradients which are less or more than r °/₀₀ (indices $'$ and $''$):

Let λ' = the length of line of gradient i';

Let λ'' = the length of line of gradient i'';

Let μ' = the length of line of gradient j';

Let μ'' = the length of line of gradient j'';

Let l = the length of line of radius of curvature ρ.

For steam traction :

$$\longrightarrow L = S + \frac{\Sigma\lambda' i' + \Sigma\lambda'' i'' - (r-1)\,\Sigma\mu'' - \Sigma\mu' j'}{r} + \frac{\Sigma \frac{800\,l}{\rho}}{r}$$

$$\longleftarrow L = S + \frac{\Sigma\mu' j' + \Sigma\mu'' j'' - (r-1)\,\Sigma\lambda'' - \Sigma\lambda' i'}{r} + \frac{\Sigma \frac{800\,l}{\rho}}{r}$$

For electric traction without regeneration :

$$\longrightarrow L = S + \frac{\Sigma\lambda' i' + \Sigma\lambda'' i'' - r\Sigma\mu'' - \Sigma\mu' j}{r} + \frac{\Sigma \frac{800\,l}{\rho}}{r}$$

$$\longleftarrow L = S + \frac{\Sigma\mu' j' + \Sigma\mu'' j'' - r\Sigma\lambda'' - \Sigma\lambda' j'}{r} + \frac{\Sigma \frac{800\,l}{\rho}}{r}$$

For electric traction with regeneration :

$$\longrightarrow L = S + \frac{\Sigma\lambda' i' + \Sigma\lambda'' i'' - \Sigma\mu' j' - \Sigma\mu''\,[\eta_1\eta_1' j'' + r\,(1 - \eta_1\eta_1')]}{r} + \frac{\Sigma \frac{800\,l}{\rho}}{r}$$

$$\longleftarrow L = S + \frac{\Sigma\mu' j' + \Sigma\mu'' j'' \quad \Sigma\lambda' i' - \Sigma\lambda''\,[\eta_1\eta_1' i'' + r\,(1 - \eta_1\eta_1')\,]}{r} + \frac{\Sigma \frac{800\,l}{\rho}}{r}$$

In the two last formulæ the symbols η_1, η_1' represent the efficiencies of the locomotive; η_1 when the motors are diving, η_1' when they are regenerating.

Generalisation of the method :

Let P be the adhesion weight of the vehicles $(1 + \omega_0)$ P the total weight of

the vehicles (locomotive and tender in the case of steam traction);
ω P = the weight hauled;
r = the resistance to rolling of the axles not motor-driven, per tonne of load;
kr = the resistance of the motor-driven axles per tonne of load.

The resistance to rolling will be :

Locomotive . . . . $k\,Pr + \omega_0\,Pr$;
Load hauled . . . . $\omega\,Pr$;
Total load . . . . $Pr\,(k\,r + \omega_0 + \omega)$.

The average resistance per tonne of *total load* will be :

$$r'' = \frac{Pr\,(k + \omega_0 + \omega)}{P\,(1 + \omega_0 + \omega)} = r\,\frac{k + \omega_0 + \omega}{1 + \omega_0 + \omega}.$$

The average resistance per tonne of *load hauled* will be :

$$r' = Pr\,\frac{(k + \omega_0 + \omega)}{P\omega} = r\left(1 + \frac{k + \omega_0}{\omega}\right).$$

Let us now assume that a train of given make-up runs over a level and straight line and on a line of given profile.

If L is the virtual length, we shall have (1) :

$$\frac{1}{2}\left(1.4\,\frac{P}{g} + 1.10\,(\omega_0 + \omega)\,\frac{P}{g}\right)v^2 + (krP + (\omega_0 + \omega)\,Pr)\,L =$$
$$\frac{1}{2}\left(1.4\,\frac{P}{g} + 1.10\,(\omega_0 + \omega)\,\frac{P}{g}\right)v^2 + (krP + (\omega_0 + (\omega\,Pr)\,S +$$
$$P\,(1 + \omega_0 + \omega)\,[\Sigma\lambda' i' + \Sigma\lambda'' i'' - \Sigma\mu' j' - \Sigma\chi\mu'']$$
$$+ P\,(1 + \omega_0).\,\Sigma\,\frac{800k'l}{\rho} + P\omega\Sigma\,\frac{800\,l}{\rho}$$

whence

$$L = S + \frac{1 + \omega_0 + \omega}{k + \omega_0 + \omega}\left[\frac{\Sigma\lambda' i' + \Sigma\lambda'' i'' - \Sigma\mu' j' - \Sigma\chi\mu''}{r}\right]$$
$$+ \Sigma\,\frac{800\,l}{\rho}\left[\frac{k' + \omega_0 k' + \omega}{r\,(k + \omega_0 + \omega)}\right]$$

Having obtained the virtual length, the consumption of energy can be deduced by multiplying L by the average resistance of the train.

$$P\ (k + \omega_0 + \omega)\ r$$

which if everything is referred to the tonnage hauled ω P, will correspond to an average resistance r such that :

$$P\omega r' = Pr\,(k + \omega_0 + \omega)$$
$$r' = r\left(1 + \frac{\omega_0 + k}{\omega}\right)$$

---

(1) Assuming that the inertia mass exceeds the gravitational mass by 40 % for the traction units and by 10 % for the hauled vehicles.

VALUES OF k DEDUCED FROM TESTS :

2 or 3-axle locomotives. — Pacific locomotive 2C1.

Adhesion weight . .	P = 54 t. (53.15 Engl. tons).	
Locomotive weight. .	90 t. (88.58 Engl. tons).	130 t. (127.9 Engl. tons).
Tender weight . . .	40 t. (39.37 Engl. tons).	

$$1 + \omega_0 = \frac{130}{54} = 2.4$$

Resistance at 70 km. (43.5 miles):

Locomotive	90 × 12 =	1 080 kgr. 2 380 lb.).
Idle axles	22 × 4 =	88 kgr. (194 lb.).
Tender	40 × 4 =	160 kgr. (353 lb.).
Per tonne of adhesion weight		18.4 kgr. (41.2 lb. per Engl. ton).

$$k = \frac{18.4}{4} = 4.6$$

4-axle locomotives. — Mikado locomotive 1D1.

Adhesion weight . . .	P = 68 t. (66.92 Engl. tons).	
Locomotive weight. .	90 t. (88.58 Engl. tons).	130 t. (127.9 Engl. tons).
Tender weight . . .	40 t. (39.37 Engl. tons)	

$$1 + \omega_0 = \frac{130}{68} = 1.9$$

Resistance at 55 km. (34.2 miles):

Locomotive	90 × 17.2 =	1 548 kgr. (3 413 lb.).
Idle axles.	22 × 3 =	66 kgr. (145.5 lb.).
Tender.	40 × 3 =	120 kgr. (264.5 lb.).
Per tonne of adhesion weight.	$\frac{1\,482}{68}$ =	21.7 kgr. (48.6 lb. per Engl. ton).

$$k = \frac{21.7}{3} = 7.2$$

5-axle locomotives. — Locomotive 2E.

Adhesion weight . . .	P = 77 t. (75.78 Engl. tons).
Locomotive weight . .	85.5 t. (85.15 Engl. tons).
Tender weight . . .	40 t. (39.36 Engl. tons).

$$1 + \omega_0 = \frac{85.5}{77} = 1.15$$

Resistance at 30 km. (18.6 miles):

Locomotive	85.5 × 21 =	1 895.5 kgr. (4 178.8 lb.).
Idle axles.	8.5 × 2.1 =	25.5 kgr. (56.2 lb.).
Tender.	40 × 2.1 =	84 kgr. (185.2 lb.).
Per tonne of adhesion weight.	$\frac{1\,870}{77}$ =	24 kgr. (53.8 lb. per Engl. ton).

$$k = \frac{24}{2.1} = 11.5$$

MEAN APPROXIMATE VALUE OF $\frac{r'}{r} = 1 + \frac{\omega_0 + k}{\omega}$

Passenger :

$\omega_0 = 1.5$

$k = 4$

ω P = 300 *t.* (295 Engl. tons) approx. $\qquad \omega = \frac{300}{54} = 5.5$

$\frac{r'}{r} = 1 + \frac{1.5 + 4}{5.5} = 2$ for $r = 4.5 \qquad r' = 9$

Goods (mountain) :

$\omega_0 = 0.5$

$k = 8$

ω P = 650 t. (640 Engl. tons) approx. $\qquad \omega = \frac{650}{27} = 9$

$\frac{r'}{r} = 1 + \frac{0.5 + 8}{9} = 2$ for $r = 3 \qquad r' = 6$

Note. — For the average train loads customary in the U. S. A., of 2 000 to 6 000 tonnes, according to the systems and the particular route, the values of $\frac{r'}{r}$ are much smaller.

Calculation of the limiting load corresponding to a characteristic gradient i_f. — The load hauled ω P is a function of the characteristic gradient i_f of the line under consideration and not of the profile proper, the characteristic gradient of a line being that which is too long to be mounted by momentum. In the case of steep gradients, if γ is the minimum acceleration that must be impressed on the train to start it, and if f represents the coefficient of adhesion of the train, we shall have :

$$1\,000\,\mathrm{P}f \geqslant \underbrace{\left[1.20\,\frac{1\,000\,\mathrm{P}}{g} + 1.10\,(\omega_0 + \omega)\,\frac{1\,000\,\mathrm{P}}{g}\right]\gamma}_{\text{accelerating force}} + \underbrace{kr\mathrm{P} + (\omega_0 + \omega)\,\mathrm{P}r}_{\text{resistance force (air+rolling)}} \ldots\ldots$$

$$\ldots\ldots + \underbrace{(1 + \omega_0 + \omega)\,\mathrm{P}i_f}_{\text{(gravitational force)}}$$

The coefficient ω which corresponds to the limiting load that can be hauled in practice on a line of gradient i_f is then defined by the relation :

$$\omega = \frac{1\,000\,f - \frac{1\,000\,\gamma}{g}\,(1.20 + 1.10\,\omega_0) - r\,(k + \omega_0) - i_f\,(1 + \omega_0)}{i_f + r + \frac{1\,100\,\gamma}{g}}$$

Conversely if we express i_f as a function of ω we obtain :

$$i_f = \frac{1\,000\,f - \frac{1\,000\,\gamma}{g}\,1.20 + 1.10\,\omega_0' - r\,(k + \omega_0) - \omega\left(r + \frac{1\,100\,\gamma}{g}\right)}{1 + \omega_0 + \omega}$$

Limiting gradient. — The limiting gradient is one on which the locomotive can haul nothing and which corresponds to $\omega = 0$.

We shall call this limit i_0; it will be defined by the equation :

$$i_0 = \frac{1\,000 f - \frac{1\,000\,\gamma}{g}(1.20 + 1.10\,\omega_0) - r\,(k + \omega_0)}{1 + \omega_0}$$

The coefficients 1.20 and 1.10 represent the added inertia due to the rotating parts. With electric traction it would be necessary to take 1.40 and 1.10 because the inertia of the electric motors is much greater than that of the balance weights, connecting rods and pistons of steam locomotives.

The value of i_0 is approximately 60 ‰, it is given by the equation above on putting :

$$\frac{1\,000\,\gamma}{g} = 6$$
$$\omega_0 = 0.6$$
$$r = 3$$
$$k = 8$$
$$1\,000 f = 1\,000 \times \frac{1}{7.5} = 133$$

Variation of fuel costs, or working costs in general, with the gradient. — Whatever the nature of the cost item considered it is possible to assume that it will be the same as it would be on the level but will refer to a smaller tonnage hauled, that is to say, that the cost per train-kilometre will be practically the same (at the same speed) as on the level, but the cost per tonne-kilometre hauled will be much greater.

This is equivalent to saying that the costs per tonne-kilometre hauled will vary as the ratio of the total weight of the train to the weight hauled :

$$\frac{\omega + \omega_0 + k}{\omega}$$

$$1 + \frac{\omega_0 + k}{\omega} = \frac{(1 + \omega_0)(i_0 - i_f) + (\omega_0 + k)\left(i_f + r + \frac{1\,100\,\gamma}{g}\right)}{(1 + \omega_0)(i_0 - i_f)}$$

$$= \frac{i_f\,(k - 1) + i_0\,(1 + \omega_0) + (\omega_0 + k)\left(r + \frac{1\,100\,\gamma}{g}\right)}{(1 + \omega_0)(i_0 - i_f)}$$

or replacing the symbols by the values :

$$\left.\begin{aligned} \frac{1\,000\,\gamma}{g} &= 6 \\ \omega_0 &= 0.6 \\ r &= 3 \\ k &= 8 \\ i_0 &= 60 \end{aligned}\right\} \qquad \frac{i_f + 7 + 60 \times 1.6 + 8.6 \times 9}{1.6\,(60 - i_f)} = 108 \times \frac{1 + 0.04\,i_f}{60 - i_f}$$

Comparison with costs for level line. — A line that is practically level has a characteristic gradient of about 2.5 % (1 in 400). The ratio $1 + \frac{\omega_0 + k}{\omega}$ has a value for the level line of :

$$108 \times \frac{1.1}{57.5} = 2.02$$

The curve representing the ratio of costs on the level to those on the gradient will, therefore, have approximately an equation :

$$\rho = 52.3 \frac{1 + 0.04\, i}{60 - i_f}$$

it being understood that for $i_f = 2.5\ ^0/_{00}$ we find $\rho = 1$.

The use of franking machines on the Norwegian State Railways (1),

by A. JYNGE,
Director of the Norwegian State Railways.

Two notes by Mr. A. Jynge, Director of the Norwegian State Railways, dealing with the use of franking machines on this system are printed below. The valuable information on this subject in them is given in reply to a question asked in a paragraph of the report drawn up for the Madrid Congress by Messrs. Bruneau, Assistant operating engineer of the French Midi Railway, and Boistel d'Welles, Chief operating engineer, at Headquarters, of the Paris-Orleans Railway.

The paragraph of the report in question was the following :

2. *Franking machines.* — Following up the same trend of ideas, the Norwegian State Railways are using « franking » machines in about fifteen of their large stations for franking way-bills of carriage paid goods. Machines of the same kind have also been installed by this administration in a number of large forwarding houses. The forwarder himself computes the carriage and prints the amount on the way-bill. The accounts are adjusted fortnightly. It would be interesting to know if, as regards consignments by weight which are subject to complicated charges, the adjustments of the charges which the railway may have to make after examination of the goods, do not diminish considerably the practical interest afforded by these machines. (This inconveniences would not, however, have any effect on the forwarding of goods on fixed charges such as parcels going through the post.)

* * *

The cost of carriage for less than full loads on the Norwegian State Railways is calculated with few exceptions on the weight of the goods and not on their value. The result is to simplify the calculations. In order to assist firms using stamping machines, the Management drew up scales of charges which give the carriage charges for the kind of consignments in question. The alterations made by the railway are in consequence few in number and have in no way lessened the practical value of the machines in question.

The checking of the carriage charges is done by the destination station which sends the invoice, after checking, to the Accounts Office which settles the matter direct with the firm interested.

Readers interested in the trials made by the Norwegian State Railways, of franking machines, are asked to read the following note on the new tariffs in force since 1927 on the Norwegian Railways.

It is interesting to note the tests made on the Norwegian State Railways whereon new methods have been applied to some

(1) Translated from the French.

extent for the calculation of carriage charges and for less than full load consignments.

Simple calculation of carriage charges. — The tests in question were made possible through the simplification of the rates system in force since 1927, for the conveyance of goods over the Norwegian railway system. In 1927 the complicated system based on the value of the goods was abandoned in favour of the calculation of the cost of transport solely *upon the weight* in the case of less than full truck loads no matter what the kind and value of the goods (excepting certain food stuffs and cattle foods which come under a special classification). As a result of this action it became very easy to calculate accurately the cost of carrying a less than full load consignment.

Standard tariffs. — With the object of simplifying the work of the railway of calculating the rates, the Norwegian State Railways have tried the application of *standard rates*, that is to say in the case of certain goods sent in standard packings of uniform size and weight the *same rates* are applied for any destination station of the State Railways (and certain stations on the privately owned lines) and *no matter the distance*. The system is the same as that the post office applies to parcels. The carriage charges are paid at the despatching station and the goods are sent as *stamped goods* (parcels).

Stamped goods (parcels). — In accordance with the regulations of the Norwegian State Railways, goods weighing less than 100 kgr. (220 lb.) and which are not to be delivered against payment (« expéditions grevées de remboursement ») may be sent as parcels when all the charges have been paid at the despatching station.

The fact that the charges have been paid is shown by the railway stamps affixed to the consignment note, the stamps being on sale at all stations, the stamps on the note being obliterated by the despatching station. Thanks to this method the accountancy and auditing work is reduced to a minimum : it is reduced to keeping account of the stamps. Lists are no longer needed.

It is quite natural that the State Railways should wish to develop this system which is well known and has been in use many years.

It has been possible to make it much simpler by purchasing *franking machines* which are now supplied to all the important stations. By this means it has been possible in these stations to extend the parcels system regardless of weight, to *all less than full load consignments* on which charges are paid before despatch, except when the goods are to be delivered against payment (expéditions grevées de remboursement).

These franking machines automatically totalise the amounts of the stamps and at the same time keep account thereof. Each time the cash balance of the machine is taken a card is automatically prepared indicating the total amount stamped up to the last settlement, and the total up to the date of the new settlement. The cashier is responsible for the difference.

The Norwegian State Railways have so far approved two types of franking machines: the « Francotyp » (Francometer) made by Messrs Anker-Werke and the « Hassler », made by Messrs A. G. Hassler of Berne.

Individual contracts entered into with private firms using franking machines.

As a result of the simplicity of the method of calculating the carriage char-

ges for less than full load consignments, it is possible to leave to the transport agents of the firms the task of calculating the charges from the detailed lists the railway puts at their disposal. In actual fact the calculation reduces itself to finding the correct figure in the list.

We have made a number of contracts with private firms according to which the latter benefit by a discount on the carriage charges : in return these firms undertake to use the railway for all less than full load consignments for destinations served by the railway. An exception is made in the case of consignments to be delivered within a radius of 30 km. (18.6 miles), for those the firms themselves can carry by their own transport, and for those in which the clients for one reason or another insist on some other given form of transport. It is understood that these firms have to calculate the charges and that the account is to be kept by means of franking machines in the building from which the goods are consigned. These firms can either buy or hire the machines themselves.

The carriage charges are subsequently paid bi-monthly according to the amount shown by the franking machines after deduction of the discount referred to above.

The firms using franking machines profit further by the removal of all doubts as regards cash payments formerly made by messengers or customers, and the account due to the railway administration is at all times shown by the machine.

A large number of contracts of this kind have been entered into with private firms and the results of this method appear to meet the object in view.

[625 .142.5]

The elastic hollow railway sleeper [1],

by Herr SCHEIBE, Finanz- und Baurat,
Klotzche near Dresden.

Figs. 1 to 5, pp. 37 to 40.

The great enemy of good track construction is *the dynamic stress caused by the rolling stock.* The injurious effects of these stresses lie in *the relative movement set up in the various parts of the track*, that is to say, loosening of the fastenings and heavy wear of all parts, etc.

The prevention of any *relative* movement between the rails and the sleepers with the sleepers remaining on the ballast without movement must be regarded as the aim of correct permanent way construction.

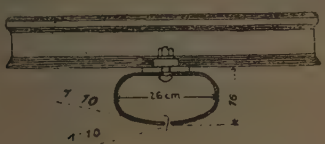


Fig. 1.

The shocks due to moving loads can be rendered harmless to the track if the rails carrying them are so firmly secured to their supports, in the form of suitably designed hollow steel members with a slit underneath, that the small vibrations, transitory deflections and compressions of the sides and superimposed parts are taken up by the *hollow sleeper* and so absorbed that they do not damage the *track as a whole.* The working stresses are transmitted unaltered through the fastenings to the steel sleepers. The immediate result is that the nuts of the bolts holding the rails to the hollow sleepers, which are screwed up extremely tight, in fact almost to the limit of elasticity, *never become unscrewed* because the condition necessary to cause this slackening, *vibration between their faces in contact*, is not set up.

As a result of the rails and sleepers being so connected together as to form a single unit, and by *keeping dynamic stresses out of the track itself*, it is possible to *get nearly equal life out of the different parts* such as rails, sleepers, fishplates, fastenings and ballast and to simplify the upkeep of the permanent way so that the traffic may not be interrupted.

A valuable additional result of the absorption of these working stresses is the protection of substructures (steel bridges and masonry).

The great utility of the hollow sleeper lies in its capacity *to absorb when in use, by reason of its elasticity, all the various forces arising from any direction*, for example, its even reaction on curves, etc.

It is clear that such a solid and lasting track offers *the least resistance* to the passage of trains and therefore influences the cost of upkeep favourably.

The extraordinary elasticity of the hollow sleeper was demonstrated in the years 1921 and 1922 at the Technical High School at Dresden by comparative endur-

(1) Translated from the German.

ance tests between the new hollow sleeper and the trough form steel sleeper hitherto commonly used in Germany and Switzerland, as to the *endurance of the rail fastenings*. In the first comparative series of tests, 67 000 blows struck mechanically, obliquely to the rail head, with a tup weighing 42 kgr. (92 lb.) falling 1.22 m. (4 feet) represented the load [1]. In the course of the test the fastenings of the rails to the trough sleepers were loosened 20 times (sometimes till the rails fell over) while under the same conditions, the bolts on the hollow sleeper only required tightening 3 times. At each blow on the hollow sleeper the tup rebounded from 10 to 12 cm. (4 to 4 3/4 inches) (fig. 2).

At the German Transportation Exhibition in Munich, in 1925, it was observed that, on a much worn section of hollow sleeper track exhibited by the Lauchhammer Works, Riesa a/E., as a result of the action of the sun's rays on hot days, the head of the rail carried *on the hollow sleepers* appeared appreciably cooler than that of the rail carried on the neighbouring wooden sleepers.

This showed that the transmission of heat from the rail to the hollow sleeper and the stone ballast was greater by reason of the more intimate connection of the parts.

In the pursuit of the study of this fact, accurate electrothermic tests were conducted in 1926 at the Dresden Technical

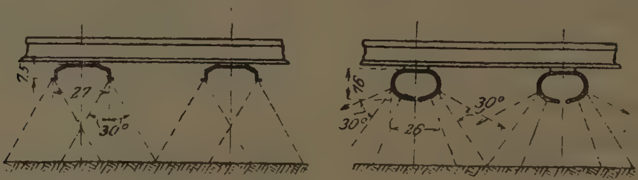


Fig. 2.

High School with rails electrically heated, which proved that the heat transferred from the rail to the hollow sleeper set up small changes in the inside measurements between the hollow sleeper walls, that is to say :

The increase in the temperature of the rails is converted into a small alteration of the cross section of the hollow sleeper and does not as at present extend on both sides along the rail length to set up dangerous stresses.

The result of this discovery is that it is possible to do away with all gaps in rail joints and the rail ends can be laid in contact, forming a continuous rail, with fishplates quite as tightly screwed up and rails equally firmly fixed to the hollow sleeper.

All the obstacles to proper maintenance which have hitherto been met with owing to the necessity for expansion gaps between the rails can therefore be eliminated if hollow sleepers are used. A self-contained, strongly connected rail system results, always resting elastically on good ballast which can no longer be disturbed by the dynamic working stresses.

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(1) *Organ für die Fortschritte des Eisenbahnwesens*, 1923.

Other peculiar characteristics of the hollow sleeper permanent way are :

1. *The long life of a sound fastening of the rail to the hollow sleeper under moving loads.*

Owing to the elastic deformation of its cross section the upper surface of the hollow sleeper conforms to the elastic bending movement of the rail, whereas, in the case of wooden sleepers, the passing wheel load induces alternating angular pressures which cause play in the fastenings on the one hand, and between the sleepers and the ballast on the other.

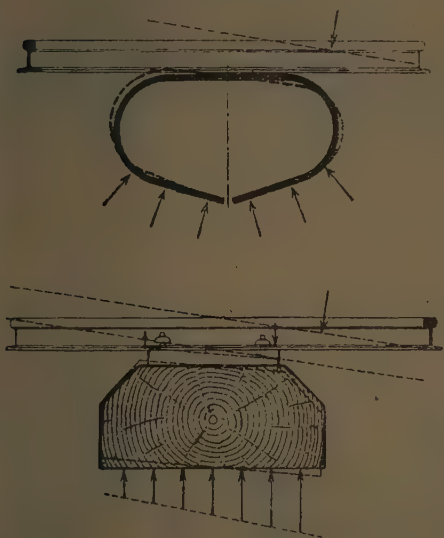


Fig. 3.

2. *Creeping of the rails*, which in the case of wooden sleepers is helped by the fastenings slackening, cannot occur with the hollow sleeper, because the longitudinal pressure on the rail in the running direction only causes a small temporary compression in a forward direction of the sleeper cross section, which does not upset the packing of the heavy ballast-filled sleeper.

Fig. 4.

3. The blow transmitted to the ballast through the rail no longer occurs because the blows caused by the passage of the rolling stock over the rail gaps is eliminated with the closing of the gaps. Owing to the small elastic changes in the cross section of the sleepers the intensity and direction of the rail shocks are met and the protection of *the rail ends* and of the ballast is assured.

4. Lateral displacements of the rails as a result of working stresses can be prevented by fixing a closing plate over the ends of the ballast-filled sleeper.

5. On lengths on which the rails are utilized for carrying current for operating signals, an alteration in the method of fastening the rails to the sleepers is necessary, so that the insulation of the rails may remain permanently unaffected.

The principle is, that the lateral movements of the rails are prevented solely by the friction obtained by high pressure holding them to the sleepers, and that the fastenings must be placed clear of the insulation. Calculations as well as official tests of the crushing strength and electrical resistance of some insulating materials have proved that it is easily pos-

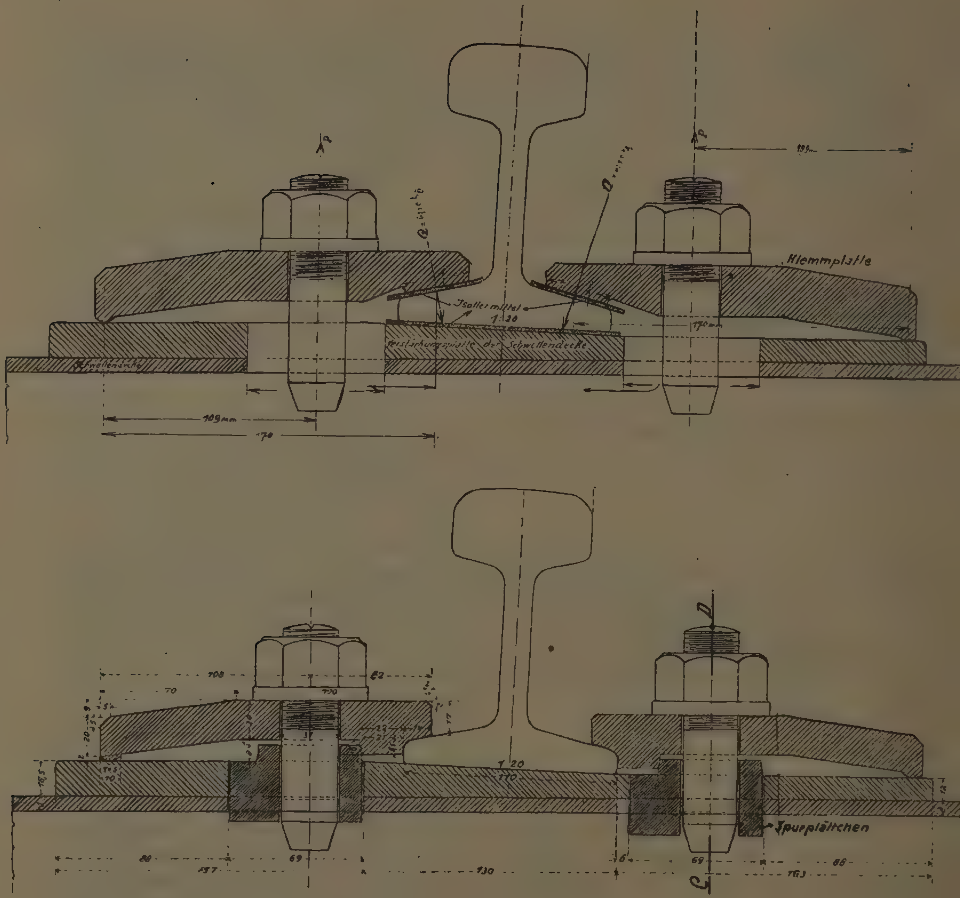


Fig. 5.

sible to fix the foot of the rail without fear of its being forced into contact with the clamping washers.

Test research is at present in progress to determine whether it is necessary to hold the foot of the rail by the fastenings.

The prevention of lateral displacement of the rail on the sleeper which would result in widening the gauge, can as a rule be more simply and cheaply achieved by increasing the pressure and so adding to the friction. The continuance of this last condition can be assured by the absorption of the working stresses in the hollow steel sleeper.

When choosing a new type of permanent way; one should not only consider the immediate saving on first cost of installation, but should consider which will give the earliest amortization of capital cost, this matter being closely connected with the cost of upkeep.

The rarity of interruptions of traffic for the purposes of permanent way repairs, which is a peculiarity of the hollow sleeper track construction, plays an important role in this connection.

In the absence of a working test, which the Management of the German State Railways has not as yet been able to make, so as not to interfere with the laying of the new (K) type permanent way, it has not been possible to make a comparison of the cost with that of the permanent way as at present in use; it nevertheless appears probable that the simplicity of the hollow sleeper track and its many good points based on its elasticity and cheapness, to which may be added the longer life of the sleeper as a result of the addition of 0.3 % of copper as a rust preventive, should result in a considerable lowering of the cost of permanent way maintenance.

[625. 14 (.436)]

New system of permanent way construction,

by FREDERIC STRAUSS,

« Modern Transport » representative in Austria.

Figs. 1 to 8, pp. 43 to 49.

(*From Modern Transport.*)

The predominant system of permanent way construction is to employ cross-sleepers embedded in a ballast foundation, the object of which is to transmit the pressure exerted on the sleepers to the subsoil and give the track the requisite elasticity. A characteristic of ballast material is that it does not completely recover from stresses imparted to it, but undergoes some very slight permanent compression as a result of each load travelling over it. The constantly-recurring longitudinal and transverse stresses cause, in addition, displacements of the ballast which in turn lead to destruction of uniformity of the foundation. The increase in transport loads has resulted in course of time in constantly increased axle-pressures, *e. g.*, Germany has at present reached 25 tons, England 23 tons, Italy 22 tons, Austria 20 tons, while in the United States of America 36 tons have already been attained. As axle weights have increased, the pitch of the sleepers (distance from centre to centre) has diminished, so that, whereas in 1868, with axle weight of 13 tons, the distance was 90 cm., today, with 25 tons, it stands at 60 cm., and with 36 tons it is still further reduced to 50 cm., and here we have reached the limit at which tamping of the sleepers is still possible. In spite of all this the wear and tear is so great that it is imperative still further to strengthen the foundation itself, and this is generally accomplished by tamping and rolling.

An entirely new device.

The question of how to overcome these short-comings in existing systems of permanent way is occupying the attention of the managements of practically every railway system. In various countries experiments have been made with concrete sleepers, but these, as was indicated in the discussions at the 11th International Railway Congress in Madrid, have up till now led to no tangible results of a favourable nature. Quite a novel system has, however, recently been invented by Dr. Alfred Wirth, a director of the Austrian Federal Railways, by whose unfortunate death, in June 1930, Austria has lost probably her most eminent railway authority. In the opinion of many leading European railway engineers this system not only overcomes present deficiencies in track work, but from the point of view of maintenance, is practically ideal. Dr. Wirth has constructed a new type of track, details of which are shewn in the accompanying illustrations, and which gives the permanent way the requisite carrying capa-

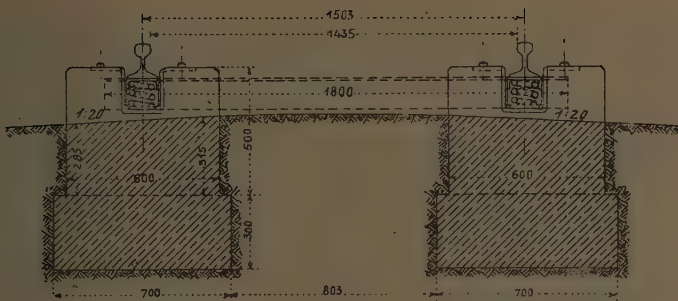


Fig. 1. — Cross section of the new system of permanent way invented by the late Dr Wirth and installed experimentally on the Austrian Federal Railways.

Fig. 2. — Experimental section, shewing method of construction.

city and elasticity without the use of ballast, and is so different from hitherto known types of track that it merely incorporates the rails themselves. An experimental section has already been laid on the main line Vienna-Gmünd (Praha), of the Austrian Federal Railways, adjacent to the Abbsdorf-Hippersdorf station. The manner in which Dr. Wirth has dispensed with ballast is by laying the rails on helical springs which are of a strength sufficient to carry the rails and give the track the fullest possible elasticity. There is nothing new in helical springs by themselves, but the idea of laying the rails on firmly

supported springs and making them yield vertically under the stress of the heaviest traffic is quite new.

The idea of the solid concrete support for the rails is not new, however, as it is already under test on the Pere Marquette Railway, in the United States, in which case the rail is given a solid and continous bearing on a concrete foundation. The difference between the system of Dr. Wirth and that of the Pere Marquette lies in the fact that the rails of the Pere Marquette Railway rest on a continous bed of concrete, but without the elasticity imparted directly through the concrete to the roadbed in the former instance, whilst in the latter it is taken by the springs, which act as an intermediary and thereby provide the maximum of ease in running.

The arrangement of the springs.

Each spring gives to the extent of 1 mm. (0.039 inch) per ton, and this is in direct proportion to the load imposed. The thickness of the special steel rod of the springs used in manufacture is 30 mm. (1 3/16 inch). Before being mounted, all springs were subjected to pressure tests in the laboratory and were exposed to pressures of 15 tons. Up to this maximum pressure all springs have sunk equally, and in every case the extent of bending was proportional to the pressure. After pressure the springs returned to their normal position without any apparent deterioration. As the maximum load on the trial line is 18 tons axle pressure, and as the distance between the supports of the springs is 730 mm. (2 ft. 4 3/4 in.), the maximum pressure on the supports falling to a single spring is about 4.8 tons, if double springs are used, corresponding to the formula of Hoffman and Schwedler. Thus the pressure on the firm supports amounts to less than a third of the maximum load of 15 tons, under which the springs have shewn complete elasticity. Even with an increase of the maximum axle pressures from 18 to 25 tons, the pressure on the supports for each single spring would not amount even to one half of the highest permissible pressure. As the strain on the springs is much less than they will take, it is not to be supposed that fatigue of the springs by reason of heavy loads will seriously affect them, nor will the breaking of a spring imply serious results to a train. During the tests a single spring was taken out and the bending was measured. The alteration from the normal was insignificant. Owing to the stiffness of the rail the load was transferred uniformly on to the next spring, which sustained very well the additional load, because it was still far from shewing the maximum permissible pressure.

The helical springs are fixed in pairs in housings on firm supports. The housings are in the nature of U-shaped iron yokes with a breadth of from one to two milimetres more than the rail flange. They are open at both ends so that the springs can be easily removed without having to lift the rails. To protect the springs two special caps and a metal cover are provided. The springs are held in position by means of four securing bolts, which are passed through the iron yoke and the masonry, and this method has hitherto proved itself satisfactory. The iron yokes are rigidly fixed to the concrete masonry by means of four bolts. The supporting masonry consists of two parts which in the construction unite to form a single unit: first there are the carrier blocks, 600 mm. (23 11/16 inches) broad and 500 mm. (19 11/16 inches) high, and then the foundation-pieces 700 mm. (27 1/2 inches) broad and 300 mm. (11 13/16 inches) high.

Reinforced concrete.

The carrier blocks are of concrete in the ratio 1 : 4 and are reinforced with iron. The distance between the carriers

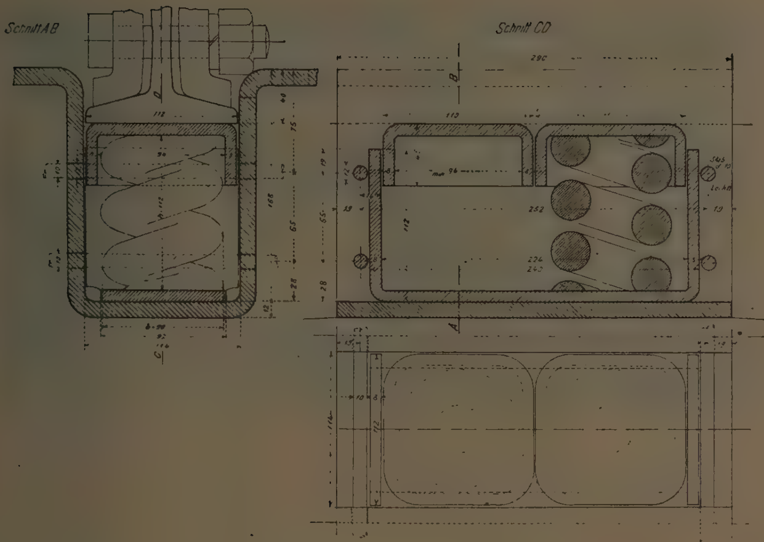


Fig. 3. — Seat and fixation of the rails.

on the 105-m. (115-yard) experimental section of the Austrian Federal Railways is 730 mm. (2 ft. 4 3/4 in.) and it is thus greater than the spacing of the sleepers on a normal track. The girder-rails commonly used are of sufficient strength to withstand the usual axle pressures, and the subsoil in the case of an axle weight of 25 tons is only taxed through the longitudinal walls to the extent of 1 kilo per cm² (14.23 lb. per sq. inch), and even loamy soil can bear that. In various places the longitudinal walls are connected together by means of transverse iron rods and masonry.

In this connection it seems interesting to deal with the question of the irregular sinking of the concrete foundation in consequence of unequal pressure or of the yielding of the subsoil. This problem has, from the beginning, occupied the attention of the inventor. The condition of the roadbed, however, was so favourable, that no difficulty whatever has been experienced in connection with the test section, and the two side walls of concrete, which are independent of each other, have proved quite satisfactory. Nevertheless, if the condition of the subsoil is unfavourable, the following measures can be taken against unequal sinking of the concrete side walls :

1. The strengthening of the side walls by means of iron supports to give them more resistance against tension;

2. The linking of the concrete side walls by means of a greater number of cross-bars, and

3. A continuous bed of concrete across the track at particularly unfavourable places.

The question of drainage has also frequently been considered by the inventor. This, however, can be dealt with by simple means from time to time, according

Fig. 4. — Constructional details of the Wirth system of permanent way. In the foreground is a U-plated iron yoke with two helical springs. The two securing bolts, which project from the concrete block, serve for the fastenings of the springs.

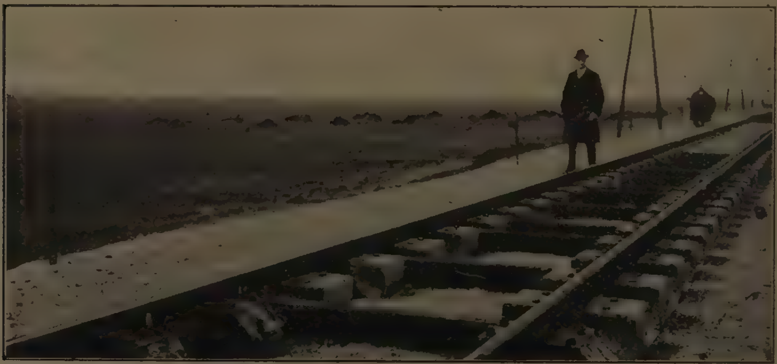


Fig. 5. — A portion of the completed test line.

to the permeability of the roadbed. Special provision on this score was not necessary on the trial line; but in difficult places a certain amount of inexpensive ballasting may be recommended. To prevent the rails from tipping sideways, and especially to ensure maintenance of the gauge, the rails outside the carriers are joined together by means of transverse angle-irons which are placed at twice the distance between the supporting carriers themselves apart. These an-

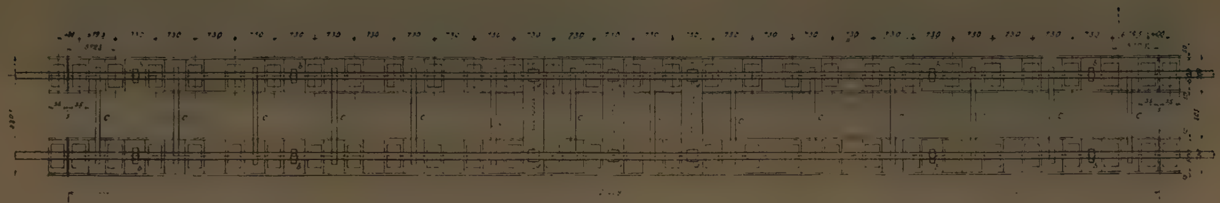


Fig. 6. — Plan of a portion of the track as laid under the new system.

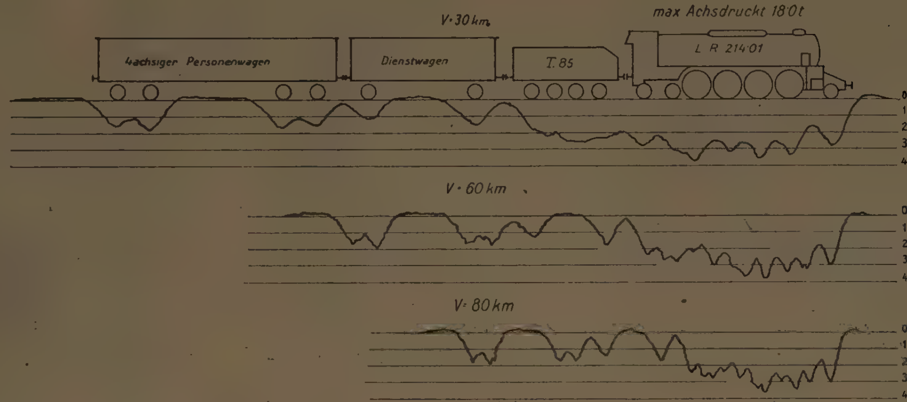


Fig. 7. — Bending of the rails under rolling loads.

gle-irons are merely bolted to the rail flange by means of screws. There undoubtedly exists some similarity to cross-sleepers, but these angle-irons differ from sleepers inasmuch as they are merely destined to act as rail-braces and to prevent tipping of the rails. They are there not to carry the rails but to move bodily with them.

Adequate safeguards.

The rails with their cross-connections together form the section of track which is borne on the springs and in the U-shaped yokes. To prevent the section from shifting in a longitudinal direction the rails are provided at their middle point with anchorages which securely hold the section to the foundation masonry without, however, interfering with the vertical movement of the rails. Three such anchorages were used over a 20-m. (22-yard) run. Then again, anchorages facing each other are connected together by transverse iron rods, and are capable of withstanding the greatest longitudinal stresses. By securing the rails in the middle it is possible for them to undergo unrestrictedly changes of length due to variations of temperature. To prevent rising of the rails above the normal position of rest, devices have been applied, as a precautionary measure, at various points of the rail to check any upward movement. These devices are placed at distances of about 5 m. (16 ft. 5 in.). In the light of experience already gained the checking devices could be so set that rising up to about 2 mm. is possible. Numerous tests have shown this lifting of the rails to be always less than 1 mm. (5/64 inch), and it only appears at the approach of the first wheel or after the passage of the last one as a result of the bending of the loaded rails.

The influence of the wear and weather.

On the combined effect of the weather and the constant hammering set up by the rolling load on the springs used in the new permanent way, the following may be said. The trial section on the Austrian Federal Railways has been continuously in operation since November 1928, *i. e.* for nearly two years, and, besides other trains, expresses have been running over it at a speed of 90 km. (56 miles) an hour. Since that time the trial line has been subjected to continued examination, consisting of a daily inspection by the ganger and a monthly survey of the gauge with simultaneous examination of the state of the concrete foundations and of the fastenings of the rails. With these there have been intermittent tests as well as an examination of the spring joints. Moreover a general inspection has taken place twice a year, in which all parts of the permanent way have been thoroughly investigated; in particular, every single spring has been subjected to a careful examination, and, where necessary, lubricated. In view of the satisfactory results of these detailed inspections it is believed, that in future it will only be necessary to inspect the track once a year. During the period of its existence the experimental line has had to endure the extraordinarily severe winter of 1928-1929, with temperatures of — 30° C. (— 22° F.), when in spite of the heavy falls of show and the severe frost, no permanent damage could be discovered to either the concrete or the iron parts of the permanent way. A slight rising of the concrete foundation (up to 18 mm. = 11/16 inch), which occurred during the winter, completely disappeared as the weather conditions improved, without causing any damage to the foundations, or to other parts of the permanent way. This result is excellent when compared with experience at this period with the ordinary permanent way adjoining the test track, where the frost caused an 80-mm. (3 5/12-inch) deflecion of the rails, necessitating the removal of the sleepers and adjustment of the road. It may be pointed out that the detailed examination of the 600 springs in the

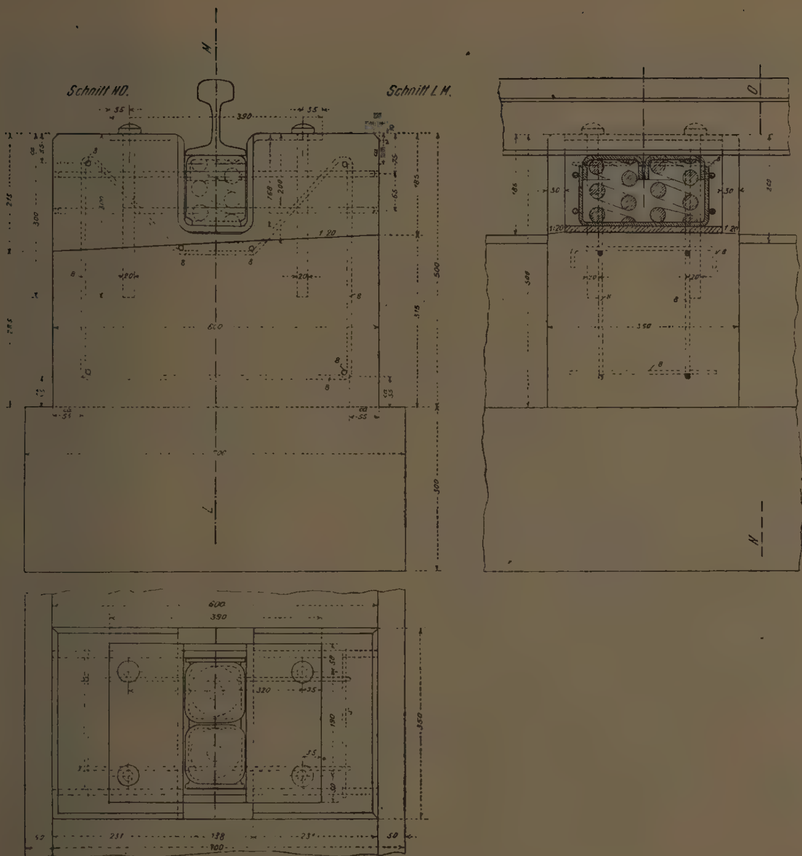


Fig. 8. — Rail support.

test section has not revealed the slightest damage.

Use on curves.

The use of this permanent way in curvature is not a matter of great technical difficulty, especially if, in the place of the concrete foundations with fixed concrete squares, the whole tracks is built on the spot as a uniform body of concrete. A short part of the trial line was built in this way with every success. Regarding the interpolation in this system of points and crossings, this aspect was dealt by Dr. Wirth in an article published in the *Organ für die Fortschritte des Eisenbahnwesens,* Number 11. (1929). From a practical point of view, however, it is not advisable to recommend the use of the permanent way on springs in stations, as it is comparatively complicated. Besides, at such places, there is no need

for this type of permanent way, in consequence of the lower speed of the trains when passing over the switches.

For bridge-work also.

Dr. Wirth's system is of outstanding importance, not only on the open track, but also for bridges, and the German Railway Company has decided to equip a 40-m. (131-foot) bridge with a double track of this nature during the present year. The adaptation of Dr. Wirth's permanent way to bridge-work is somewhat as follows : The rails are no longer laid directly on springs and they are not supported directly by the rail-flanges, but indirectly by means of special carriers. The demand for devices protecting against derailment made it seem most suitable to lay the rails, as in the case of other permanent way, on transverse iron sleepers, to make these sleepers correspondingly strong so that the guide rails could hold the bridge flooring and also withstand the thrust of a derailed wheel, and then to lay the sleepers themselves elastically on the springs by means of the aforementioned special carriers. As regards the application of the system to lines with electric signalling, insulation will have to be effected, on the one hand, between the iron cross-struts and the rails, and, on the other, between the rail and the concrete supports.

Relaying during traffic.

It is to be supposed that Dr. Wirth's system of permanent way will be used chiefly on main lines with heavy traffic, which, as a rule, possess two or more tracks. If traffic conditions permit, it will, of course, be advantageous to close the line during reconstruction between adjoining stations. If this is not possible, the line in question would have to be occupied for about a mile at a time, traffic being meanwhile diverted by the use of temporary cross-overs. If this latter measure is not feasible, a third method might be adopted. The existing track, with its sleepers, for a not too long distance might be raised for about 35 to 40 cm. and temporarily supported. This inexpensive lifting would be sufficient to enable the building of the concrete foundations as well as the mounting of the rails under the lifted track. This portion of the new track having been completed, the building materials which had been used for the lifting, could be similarly employed for succeeding sections.

Cost of the system.

As regards the cost of installing Dr. Wirth's system of permanent way, no definite statement can at the moment be made, but, generally speaking, the initial cost can be reckoned not to exceed two and a half times the cost of installing an existing type of main line permanent way. Maintenance expenditure will, of course, depend on local conditions, but it will be far below that of ordinary track. The maintenance costs of the trial section on the Austrian Federal Railways, amount to only twopence per running metre per year, against 1 sh. 2 d. for the ordinary permanent way. Furthermore, it can be confidently asserted that wear and tear of rolling stock will be less, and the savings under this head will be considerable.

[656. 21 (.42) & 656. 225 (42)]

Tranship traffic.

A scheme under consideration by the Great Western Railway for eliminating small tranship stations,

by H. W. PAYNE,

District Goods Manager, Newport, Great Western Railway (Gt. Bn.)

Figs. 1 to 5, pp. 52 to 60.

(*Railway Gazette.*)

In coming to grips with any problem, procedure is all important, and never more so than in this particular case.

The rough idea has been to schedule a number of tranship stations for abolition and to retain others as key points.

Those to be abolished are so designated because primarily they are small : those to remain are primarily large or large enough by comparison with others in this or that area, which fulfil a very limited, if useful function, which could be transferred elsewhere.

There is sound reason in attempting to get rid of the little places. Junction location apart, and this can be over-estimated, little tranship stations are necessarily of small loading influence, which is of a local character, and what traffic flows through such places for other than local station truck distribution has to be loaded on again. This disability in great measure disappears at large places. Here the radial connections are numerous, the concentrated loading gives a high percentage of « through » wagons received and forwarded, and the trunk line train services expedite the transits to destinations or the next large tranship station.

A glance at the loading charts A and B (figs. 1 and 2) illustrate the position at a large and a small tranship station.

Similar charts to those reproduced have been prepared for each of the 52 tranship stations on the Great Western Railway, and as a preliminary, 34 of these 52 are now under examination.

The remaining 18 are earmarked to remain permanently, but this is not final. It is sufficient to base a working hypothesis in this way upon 34 to go, 18 to remain, with power to add to or subtract from either figure.

The selection is not entirely rule of thumb, but the traffic movements are as yet in the statement stage, and an interesting phase of the work has here presented itself.

A special record of one week's shed traffic of all descriptions has recently been taken at the 34 stations, and the proposition is to render, in terms of a representative day's work, an intelligible picture which can be associated with other pictures ultimately resolved into an alternative scheme designed to give the desiderata of :

a) One transhipment,

b) Quicker transit between two points, each being interactive.

The traffic has to be measured, from the single consignment to the massed weight of many consignments passing through each given station. Direction

Fig. 1.

Chart A. — Loading of direct wagons, station trucks and pick-up trucks, to and from Bristol, shown diagrammatically.

must be known, together with previous and subsequent interception where this has taken and will take place.

An experimental way of graphically setting this out has been adopted : See charts C and D (figs. 3 and 4).

To prepare C, a weight summary of the individual entries taken originally from the transfer invoices has been made, and has been associated first with the tranship stations nearest on each side to the one under examination. This gives the last « loaded from » and « loaded to » weights, and, taking the whole of the stations next in line to the centre, produces in weight and direction the total inwards and outwards traffic less the « Town » or originating weight at the centre line station.

Step by step, outwards from the centre line, the points of transhipment diminish directionally until the traffic

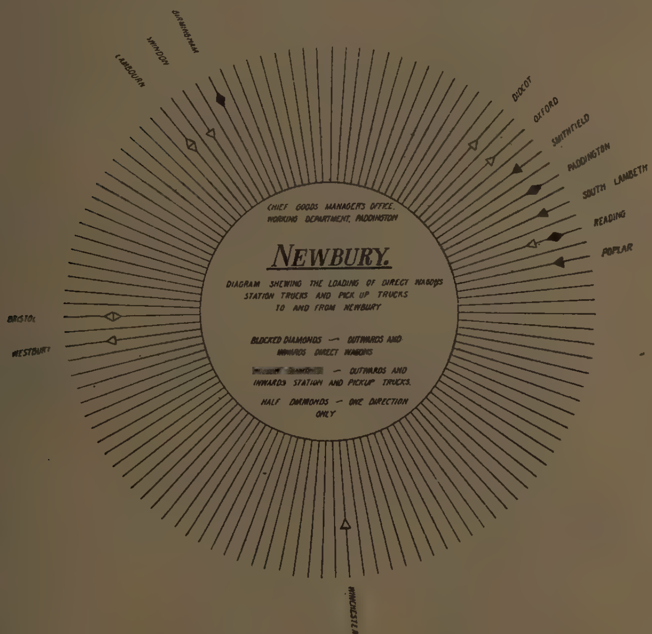


Fig. 2.

Chart B. — Loading of direct wagons, station trucks and pick-up trucks. to and from Newbury, shown diagrammatically.

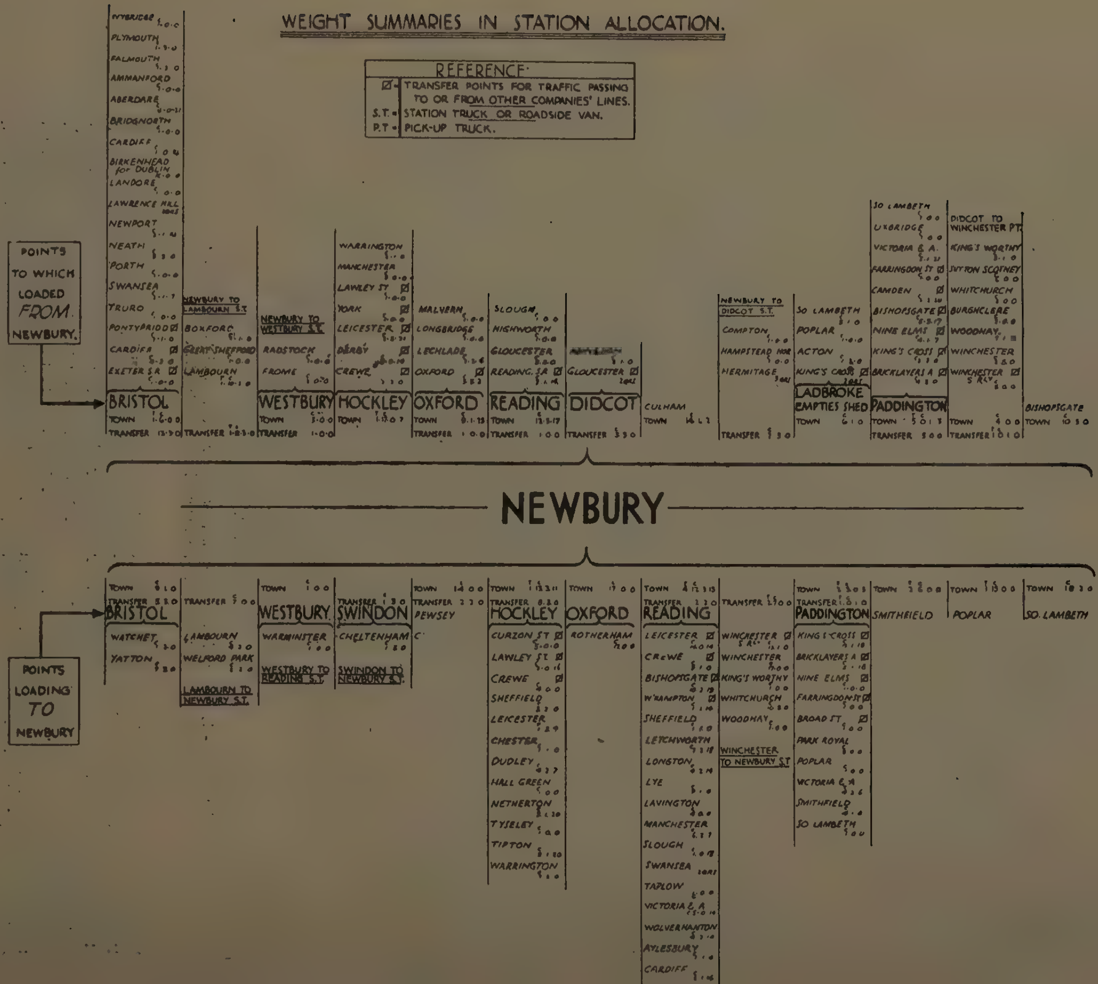
for the farthest distances becomes local to the last tranship point, is for distribution by a « foreign » company, or has originated in a similar manner.

Chart D is a closer analysis of C. It also is approximately a geographical delineation of journeys showing the several other tranship depots within the area which are scheduled to disappear under the scheme. Each of the 34 stations will have charts C and D prepared, and by process of association of weights, lines of movement, with due regard to origin and ultimate destinations, a re-

WEIGHT SUMMARIES IN STATION ALLOCATION.

REFERENCE.

☒ - TRANSFER POINTS FOR TRAFFIC PASSING TO OR FROM OTHER COMPANIES' LINES.
S.T. - STATION TRUCK OR ROADSIDE VAN.
P.T. - PICK-UP TRUCK.



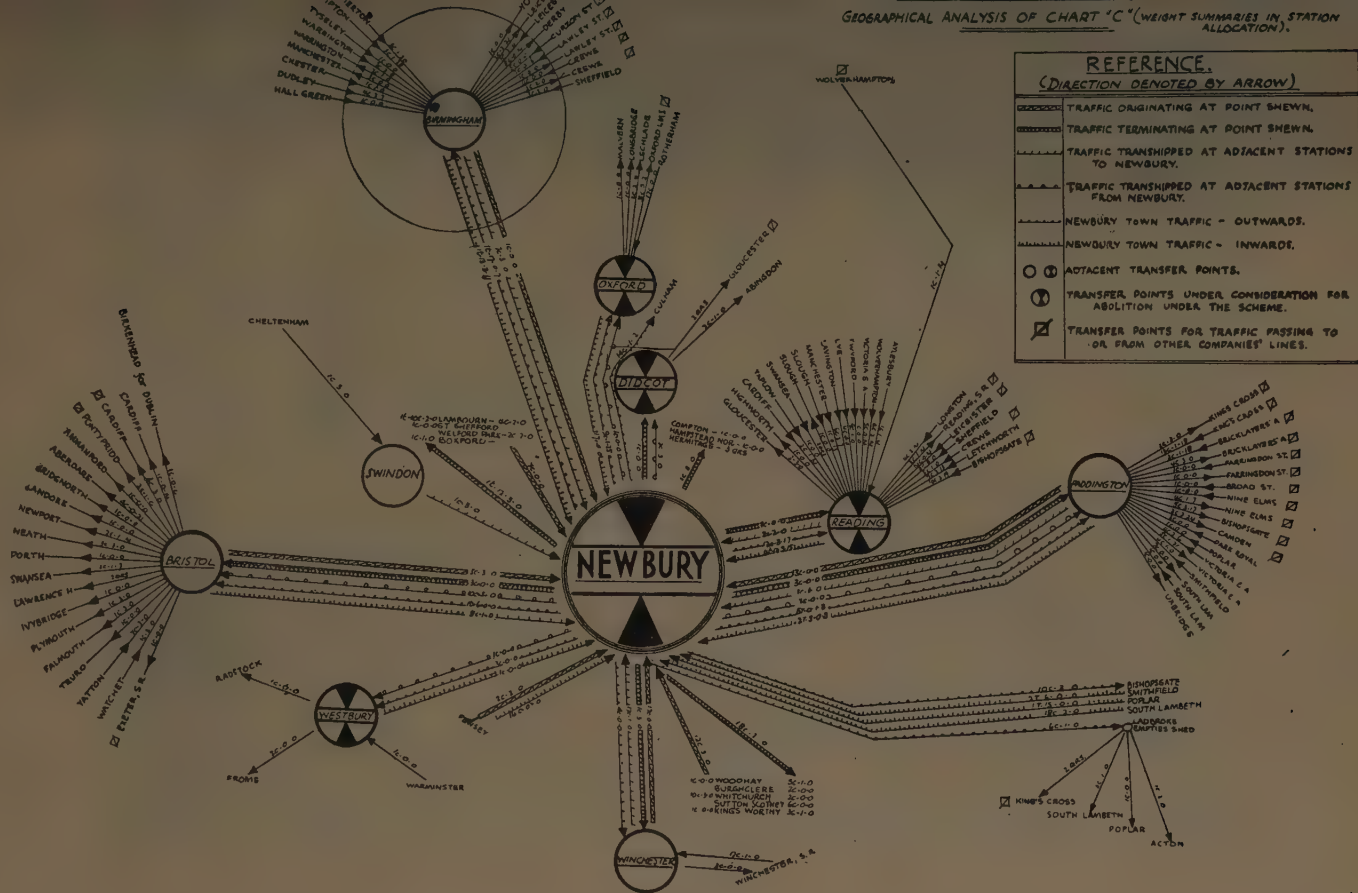


Fig. 4.

Chart D. – Geographical analysis of Chart C, weight summaries in station allocation.

casting of the tranship map will be brought about.

Essential in the somewhat formidable task of seeing the wood and the trees at the same time will be the standard loading ability (example A and B) of the more important stations, which is susceptible of expansion in the matter of truck loading capacity alone, and of additional wagon per train, given the necessary standing accommodation.

The load per wagon from the large stations will improve, it is fully expected, and this may be taken as meaning that a « through » or direct wagon will carry a greater number of small consignments to destination or with one transhipment only.

Where a reduction in the minimum load of one ton now insisted upon is precedent to giving the same improvement from stations where the sphere of loading influence is less effective, there will be no hesitation in testing the weight to ascertain what new minimum should be adopted to ensure the wagon having a through run.

. The statistics for the week recently recorded have provided for a diminishing division of weight down to 10-cwt. lots accordingly.

Finally, the « town » traffic which, be it remembered, has been or will become either wholly or in part tranships at another station on its journey, falls to be dealt with if the natural outcome of diversion of tranships is to be an economy in station establishment expenditure only to be realised by closing the shed — the yard and mileage traffic must, of course, remain.

Road conveyance to the nearest centre allocated for the concentration of an enlarged area of transhipping is postulated.

The cross-country road lorry services already function at 120 Great Western stations, and are still growing. Their enlargement to encompass this redistribution as tributary to main-line operations is easily within the realm of practicability, and the new programme foreshadowed in these notes will pay due attention to the advantages of the greater mobility of the road vehicle for between station working.

* * *

It is not primarily a feature of the re-arrangement of tranship depots that there is to be a new or enlarged concentration station equidistant from a number of « condemned » tranship points. Decisions are not governed by geographical questions entirely, but depend in appreciable measure upon the the principal centres of traffic density, which must continue to exist and are to-day of high value as traffic distributors.

The elimination of the « condemned » places will involve the element of overcarrying, which will be worth while in that the one transhipment at a large centre will mean better opportunities of « through » wagon loading to destination, apart from other suggested expedients for expediting transit which are dealt with herein.

The outline conception of a change, however strategically wise, must eventually be much preoccupied with the detailed localisms of all the tranship stations affected, and as practically all the stations in each existing sphere of influence of a tranship centre are affected, the whole line comes under review. The disturbance of established transhipment operations at a station has a number of reactions which contain within themselves all phases of freight handling and movement.

The tranships passing through the station provide, with the local town traffic, a truck-loading datum which determines the number of « through » or fully-loaded wagons — observing, of course, the present standard minimum of 1 ton per truck. The « through » wagon loading is much depreciated by the disappearance of the tranships, and

therefore the town traffic — both inwards and outwards — must either run the risk of retarded transit or be catered for in some other way.

As a concentration point, the tranship depot, small or large, has an importance for distributive or on-loading ability based primarily upon the number of direct wagons it can load to destinations or to the next point for further transhipment (in which is included the originating or town traffic amalgamated with the passing loads), and the local forwardings by « station » trucks which stop and deliver or pick up wayside station traffic over itineraries arranged to meet the requirements. How little or how much of « received » and « forwarded » traffic other than tranships is at a disadvantage depends, of course, upon the size of the station and the locality served, but it remains for treatment, which suggests itself in two ways.

One is to convey traffic by road to the new concentration depot and at the same time serve the small stations now served by the station trucks, and so close the shed. This is not, be it noted, closing the goods station entirely. Almost without exception there is the yard or mileage side of railway business, where, particularly in rural districts, bulk traffic appropriate to local industries is received or forwarded without delivery or collection facilities being required from the railway company, traders, farmers, and the like having their own cartage equipment. The station must therefore remain, if necessary, for the reception of small miscellaneous merchandise. But economies in personnel and establishment costs are possible with the main proportion of goods handled elsewhere.

The principal consideration in respect of the road service is the distance to be travelled in collecting and delivering from a new location over a dispersed itinerary. Morning and evening attention to towns and villages will have to be arranged at times convenient to the trader and consistent with the distant station operations of unloading of inwards wagons for delivery and of loading of outwards wagons against train-departure times at night. The scheme is practicable given these conditions, and above all, the transit of the traffic diverted is improved.

The other way is to send the tranships to a better concentration depot and revise the truck loadings for the miscellaneous town traffic. The shed establishment and staff must remain, although not of the same dimensions. Aiming at as much through loading as can possibly be managed, and in the pursuit of the best transit, a reduced minimum of 15 cwt., or even 10 cwt., is justifiable both for the direct run to destination or to the one unavoidable tranship station. Traffic in both directions should be borne in mind. The smaller lots will then be handled by the station trucks working between the larger centres and those intermediately disposing of the goods for local areas.

This is open to criticism as a retrograde step unless it be practicable to improve such working — that is to say, to get the town goods to the new points of distribution in time to catch the principal trains to destination — a questionable proposition having regard to the essentially « stopping » characteristics of the cross-country train services upon which the station trucks move about their business.

The road element is new in this legislation towards quicker movement in those areas where density of traffic is not comparable with the industrial and large-town regions situated upon the main lines. Rail traffic proper, as distinct from road-borne traffic in sporadic consignments or the rural activities of the country lorry services, is here under notice, and road conveyance means extra expense. That in itself is commercially sound if the business is retained and increased, and an attempt to balance

Method of tabulation of formula headings.

FORMULA.

The alternative tranship point. Or a new depot at a new location.	Its geographical convenience, present capabilities as a concentration point, and its susceptibility of expansion to the degree required.
The diversion of traffic from one or several places to other places.	The weight involved.
Capability of the alternative tranship point in respect of :	Existing loading facilities. New loadings necessary, including « station » trucks, based upon the station as a sphere of influence for wayside stations. The abolition of these wagons wholly or in part as the result of introducing or expanding road services. Improved transit to be secured by reducing the standard minimum load for « through » wagons to 15 cwt. or 10 cwt. The total number of additional wagons. Shed accommodation. Staff employed. Proposals as to road services.
Weight of tranship traffic receiving improved transits as the result of the new scheme.	By substitution of « through » loading. Reduction in number of transhipments. Road service.
Effect of diversion of tranship traffic on the transit of town traffic from the transfer centre to be abolished.	Weight of town traffic. Alternative methods of disposal. Road service. Alternative tranship points. Effect on transit: improved, unaltered, worsened.
Road conveyance from a concentration centre.	Centralised invoicing, delivery sheet and accountancy operations.
Station truck working.	Both in respect of the station listed for closing and the alternative station, with particular regard to the interstation operations not directly affecting the centre under notice.
Wagon loading.	The consequence of concentration and aggregations of traffic. The high-capacity wagon for general merchandise. The reduced minimum load.
Train services.	Adjustments to meet the altered flow in various directions.
Station shed and yard establishment.	The closing of the shed and resultant saving in personnel and in other directions — the cost of handling.

the additional cost by a saving in railway operations rendered redundant can be made.

Reference has already been made to the complete or partial abolition of personnel and establishment, the one the cost of handling per ton, the other the associated outlay involved in maintaining all that is understood by the railway goods shed and connected premises. Where the staff disappear, the buildings can be utilised as warehouses for bulk or railhead traffic, susceptible of delivery to the door of the consumer by the company's growing equipment for this purpose. In addition, there is to be taken into account a saving in wagon mileage and of engine operations in and about the shed, but this is qualified appreciably by the retention of the station for yard and mileage traffic already touched upon.

How far road services are practicable and desirable as replacing short-distance goods trains is dependent upon actual road distance from the railhead served by the fast goods trains, the intermediate activities of the station trucks to be abolished, and the quantities of goods to be disposed of to and fro. The road itinerary may be likened to an extended delivery with the stations on a line of route as the calling places.

Whether in practice actual door-to-door deliveries direct from the base station are preferable to station calls is a question to be decided by local circumstances governing this or that station. In point of time and cost of cartage equipment for direct and less interrupted runs the station call is preferable, but the circulation of the goods to and from the stations must presuppose the existence of local cartage or the auxiliary of the country lorry service already working over the ground. Expense apart, the extended delivery to door is the ideal, but for the various reasons given the identity of the small goods station cannot be destroyed, and the problem of duplicate services, overlapping and wasteful journeys, faces the reformer.

Time saving is the beginning and the end of the effort to reform, and over-attention at first to expense may jeopardise the advantages in operation, and the increased business, it is fully expected, will follow upon reorganisation independently of station economies. With this leaning towards road transport for cross-country « small », traffic which is thereby converted into railhead distribution, the selection of new centres has to be taken a step farther, where long-distance cartage over scattered country districts is uneconomic.

A central road clearing house is postulated with due regard to intermediate handling, which it is the object of the scheme of reorganisation to cut out. The superiority of such a concentration over a rail depot lies in the mobility of the road vehicles, their movement independently of train formation at scheduled times, and a liberty of loading in areas as against line directions. In other words, circumference, by comparison with diameter, traversed in less time.

This « geometrical » reflection is worthy of emphasis, because a further analysis of cross-country work has brought prominently to notice that in contemplating a replacement of conveyance for small and miscellaneous consignments of freight traffic there is a by no means negligible quantity of wayside inter-station carryings without transhipment which are now performed by the station trucks in the course of their journeys, and provision must be made for these.

To sum up, at this stage of the inquiry the major and minor problems which arise for consideration in this connection are susceptible of tabulation under formula headings which are set out above. They are to be read upon

Full truck loads.

Composite loads of miscellaneous merchandise traffic for transhipment, but including town traffic for the tranship point.

Direct wagons of town traffic for the tranship point.

« Station » or « pick-up » trucks.

From starting point to tranship station. Intermediate station work including tranship and town traffic for the tranship station.

From starting poi
tranship station
« pick-up » truck,
tranship or town tr
for the tranship p

TRANSHIP GWR STATION

Composite loads of miscellaneous merchandise (including traffic originating at the tranship station) to tranship stations, with town traffic for those points.

Direct wagons of town traffic (including traffic originating at the tranship station) for destination.

Full truck loads.

From tranship station (including traffic originating at the tranship station) to destination. Intermediate station work, including town and tranship traffic for terminating point.

Station trucks.

the assumption that the various lines of traffic have been examined in detail, that decisions as to diversion have had the main object of the investigation — speedier transit — conspicuously in the foreground, and that the answers to the questions point to the one conclusion, that the tranship station can be dispensed with, with all-round advantage.

Finally, a résumé of this analysis, giving in terms of weight and transit time the result of the revision which will be the guiding factor in a decision to abolish or retain the station.

[625 .258 (.73) & 656 .254 (.73)]

The Pennsylvania installs car retarders in Pitcairn Yard, near Pittsburgh, Pa.

Figs. 1 to 4, pp. 63 to 66.

(From *Railway Age.*)

Since November 1929, car retarders have been in service in the eastbound classification yard of the Pennsylvania at Pitcairn, Pa., 15 miles east of Pittsburgh, Pa. As this yard was previously equipped with power-operated switch machines, an ideal opportunity is now afforded to study the cost of yard operation as formerly conducted with car riders, compared with the present method of using car retarders without riders. As will be explained in detail later, it may be mentioned briefly here that the operation has been speeded up, with the result that classification is now handled with two tricks and the net saving in operating charges over and above interest and depreciation on the expenditure for retarder apparatus equals approximately $153 000 annually.

The yard includes 34 tracks with a total capacity of 1 700 cars, the longest track holding 68 cars and the shortest 17 cars. The length of the tracks is limited by the topography, as will be seen in the illustrations.

Changes in track layout.

The yard was previously arranged on the ladder principle with five ladders. In order that the yard might be better adapted for retarder operation, and also to reduce the number of retarders required, the track leads were rearranged in six groups, five of which include six tracks each and the remaining group four tracks. New No. 10 turnouts were used to replace the No. 8 turnouts. At the same time the grades were revised throughout the area, including the retarders and switches as shown on the profile. A non-accelerating descending grade of 0.3 % extends from the clearance of each turnout on each track throughout the classification yard.

The switches in this classification yard had previously been operated by direct-acting, electro-pneumatic power switch machines controlled by a push-button control machine in a tower near the apex of the hump. The same type of power switch machines were included in the new arrangement, but the old push-button machine was removed, the switches now being controlled in conjunction with the retarders in three separate towers.

A. total of 25 single-unit, double-rail retarders were installed in this yard. The throat of the yard lies in a deep rock cut, which restricts the layout, so that some of the track groups start farther from the hump than others. This difference in the length of the leads made it necessary to use more retarders for some routes. For example, a car passing from the hump to any track in group 1, 2 or 3 passes through a total of six single-unit retarders, while a car going to any track in group 6 passes through nine single-unit retarders. A power skate machine is located at the clearance point on each track. The con-

trol machines for the retarders, switches and skates are located in three separate towers, each machine having control of a certain area as indicated on the sketch. The retarders, power switches, signals and control machines were furnished and installed by the Union Switch & Signal Company.

Class and volume of traffic.

This yard is used exclusively for high-class, eastbound traffic, about 90 % of the cars being loaded, the lading consisting principally of merchandise and manufactured products. The several western lines of the Pennsylvania from Cleveland, Detroit, Toledo, Ft. Wayne, Chicago, Columbus, Indianapolis, St. Louis, and Cincinnati, all converge into Pittsburgh. The eastbound high-class freight traffic on these routes is handled in scheduled trains each bearing a name as, for example, the « Cincinnatus », which leaves Cincinnati at 6.00 a. m., and is scheduled to arrive in Pittsburgh at 11.30 a. m., with delivery in New York the third morning out of Cincinnati. A great deal of this eastbound through traffic passes through the Pitcairn classification yard.

In addition to the through eastbound

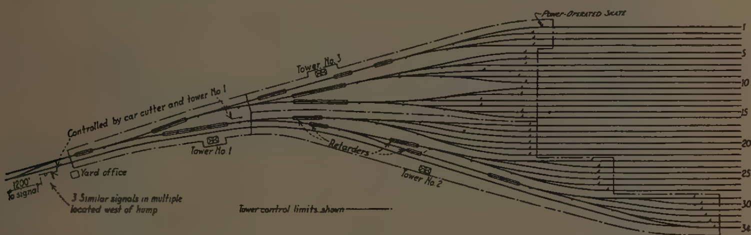


Fig. 1. — Layout plan showing location of retarders and switches.

traffic from the western lines and connecting roads, Pittsburgh itself with all its great industries, is an important originating point for freight traffic. Of the eastbound loaded cars classified at Pitcairn, about 55 % originate in the Pittsburgh area. This traffic is collected from the various industries and delivered to the receiving yard in trains operated on regular schedules similar to those arriving from the west, which altogether total 16 trains daily.

In the first place, these trains must arrive on schedule in order to prevent congestion in the receiving yard, which consists of 13 tracks, the longest holding 80 cars and the shortest 15 cars, with a total yard capacity of 866 cars. This whole yard lies on an ascending grade of from 0.8 to 1.0 %, which further adds to the difficulties, but cannot readily be changed on account of the topographical limitations.

As soon as a train arrives, the conductor delivers the bills of lading to an office at the entering end of the receiving yard. Then a « checker » checks these bills against the cars and sees that the bills are arranged in the order that the cars stand in the train. This checking being done at the average rate of 100 cars an hour. The bills are then delivered to the yardmaster's office, where a switch list is prepared showing the number of the car in the train, starting with the first car to be pushed over the hump; the initials of the car; a designation as to whether the car is light loaded or heavily loaded; and last, the number of the classification track to which it is

to be diverted. This list is typed on the sending machine of a teletype system, the list being printed simultaneously in each of the retarder towers. While these operations are being done, car inspectors are inspecting the train. In the meantime, the humper locomotive has been coupled on and at the end of a period of about one hour after the train arrives in the receiving yard it is ready to be classified.

The assistant yard master in charge of the humping operation is located in a small building at the apex of the hump. On his desk are small levers for controlling the hump signal, and below these levers are buttons for controlling air-operated horns located along the receiving yard, by means of which he can sound certain signals for starting or stopping the humping; these horn signals are of benefit particularly during foggy weather.

The entire receiving yard is on a grade of 0.8 to 1.0 ascending toward the hump and the approach to the hump is on about 2.5 grade for 250 feet in advance of the apex. Therefore, it is highly desirable to prevent interruptions to the humping operations that would require the train to be stopped. Ordinarily the cars are pushed up to the hump at an average speed of about 3 miles per hour. As soon as the last car has gone over the hump, the locomotive is moved out of the way of the next train to be humped, in order that continuous operation may be assured. Sufficient locomotives are used to have following trains waiting just west of the apex of the hump ready to start operation immediately after the last car of the preceding train has been humped.

Fig. 2. — One of the six-track groups.

As the cars pass over the hump the « cutter » uncouples the cars into the various « cuts » according to the switch list. As explained previously, each retarder operator has a copy of this list and manipulates his switch and retarder levers to divert the car to the proper track and control its speed properly so that it leaves the last retarder at a speed that will not cause damage to other cars on the track. Track circuits are provided to prevent a switch being moved under a car. The grade of the classification yard tracks is such that the cars will not accelerate after leaving the retarders. A telephone system with a transmitter and loud speaker in each re-

tarder tower and in the assistant yard master's office affords immediate communication concerning the movement of cars.

Hand-placed track skates are used at the east end of the classification yard for the protection of clear tracks. Two brakemen secure the hand brakes on cars after they have been stopped at the east end of the yard by the use of the hand-placed skate. A skate is replaced when a track is « pulled ».

Cars are pulled from the classification track at a predetermined time to permit trains to be prepared for handling over the Allegheny mountains on the eastern part of the Pittsburgh division. The departure operations consists of adjusting the piston travel, stopping of all train-line leakage and testing, adjusting and repairing of all retaining valves. A train is ready for departure about one hour after the cars are pulled from the classification tracks. On the average about four hours' time elapses from the time a car arrives in the receiving yard until it departs in an eastbound train. Only 2 h. 30 m. are allowed for handling some of the through traffic from the time the train is scheduled to arrive until it departs eastward.

Fig. 3. — A skate-placing machine with cover removed.

Comparison of operating results.

With the previous method of operation using 18 car riders on each trick, an average of about 600 cars was handled every eight hours. However, with the car retarder system as high as 960 cars, in cuts averaging 1.4 cars per cut, have been classified in one eight-hour trick. When pushing at the rate of 2 miles per hour, 2.5 cars pass over the hump each minute, at which rate approximately 1 200 cars could be classified in one trick, if the traffic were available. The limiting factor in the yard operation is that the speed of the car when leaving the last retarder in the route must be

low enough not to cause damage when striking other cars.

The increased speed of operation made possible by the new facilities has made it practicable to reduce the yard operation to two eight-hour tricks a day. In order to fit in with the scheduled time of arrival and departure of trains, these periods of operation are from 8.00 a. m. to 4.00 p. m. and from 8.00 p. m. to 4.00 a. m. Overtime has not as yet been entirely eliminated, but this feature is not excessive, and is not a daily occurrence. It is, of course, largely dependent on arrival of incoming trains. This arrangement has not delayed the departure of trains; in fact, it has made it possible to make connections with scheduled outgoing trains even when incoming trains are late. This result was made possible by the fact that the entire yard capacity, approximately 150 cars an hour, is available at all times, no delays being caused by waiting for riders, etc.

The use of the car retarders, together with the elimination of one trick of operation daily, has permitted a reduction of 76 men employed in the yard, which makes a total wage saving of approximately $444.95 daily. Also, the two-trick operation has permitted the release of four locomotives at a total saving of $40 296 annually. In addition, the motor cars formerly needed to haul the car riders are no longer required, with an estimated saving of $1 210 annually, or an estimated gross saving per year of $203 913. This gross saving is, of course, partly offset by interest and depreciation on the car retarder apparatus, increased cost of electric power, and maintenance of plant over and above the cost of the old arrangement, all of which amounts to about $50 915 per year, or an estimated net saving of $152 998 annually.

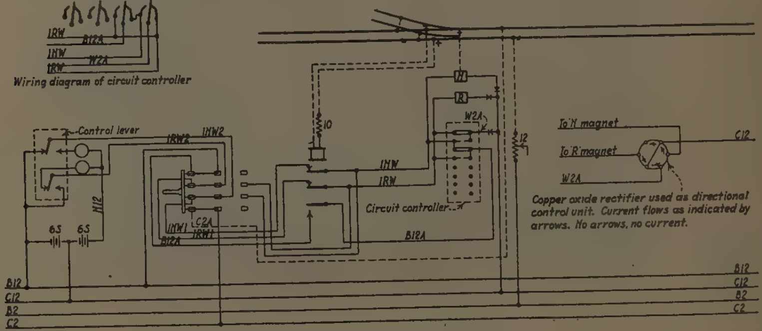


Fig. 4. — Diagram of circuit for the protection of switches.

The retarders, switch and skate machines are the electro-pneumatic type manufactured by the Union Switch & Signal Company, the compressed air for operation being secured from the compressors in the car shops about one-half mile away. The air lines in the yard are of wrought iron pipe, buried to a depth of 30 inches below the rail level. The circuits for control of the retarders, switches, skates and signals are all run underground in lead-covered steel-taped parkway cable. A 6-conductor No. 14 cable runs from a control tower to each retarder and a 7-conductor cable from a tower to each switch. A 4-con-

ductor cable extends from the main battery in the yard master's office to a centrally located instrument case from which point a similar cable is run to each tower and the other instrument cases. A 5-conductor No. 10 cable for the 110-volt, a. c. lighting and battery charging extends from the yard master's office to the instrument cases. A 3-conductor No. 14 cable is used between a tower and each skate machine, and the track connection leads are single-conductor No. 9. The underground parkway cables are terminated in a box at the base of each tower, from which point single conductor No. 14 insulated wires are run in conduit up to the control machine located in the tower above.

In the area including the retarder layouts, the yard is built on solid rock so that all the trenches for the air line, as well as the cables, had to be blasted. The wires were furnished by the Kerite and Okonite Companies.

A track circuit is provided at each switch layout to prevent the switch being thrown under a passing car. The extent of the track circuit and the control circuit are shown in the diagram (fig. 4). It should be noted that a four-pole double-throw switch is provided so that if the track circuit fails it can be cut out so as not to interfere with the operation of the yard while repairs are being made.

The control battery consists of 12 cells of Exide type EMGO-7 battery with 120 ampere-hours capacity, being on a. c. floating charge of about 3.5 amperes from a Union rectifier.

Although some of the traffic was diverted to other yards, the major portion of the regular business was classified in this yard during the reconstruction period, certain tracks being out of service at different times. In order to reduce the time required to install the retarders, each retarder was constructed complete with rails and ties in place at a location at the side of the yard. The retarder ties are 7 inches by 9 inches by 10 feet treated oak. The entire layout was placed on a flat car by a crane and then set in place in the track. As soon as the ties were tamped up the track was again ready for service. The retarders in the main leads were placed on Monday, the light-traffic day, but the remainder were set without serious interference with yard operations.

[625. 258 (.73) & 656. 254 (.73)]

Car retarders installed by Chicago & North Western at Proviso Yard, near Chicago.

Figs. 1 to 3, pp. 69 to 73.

(From *Railway Signaling*.)

The car retarder system is one of the most important features of the new inbound classification yard of the Chicago & North Western, at Proviso, Ill., about 14 miles west of the business center of Chicago. Proviso is located strategically with reference to connecting lines, as well as to the four lines of the North Western radiating to the west and north of Chicago. The yard lies just north of the Galena division, or Chicago-Omaha main line, at a point just west of the overhead crossing of the Indiana Harbor Belt line connecting with railroads to the East. Likewise, Proviso is the southern terminus of the so-called Des Plaines Valley line, which connects the Chicago-Omaha line with the Chicago-St. Paul line at Des Plaines and the Chicago-Milwaukee freight line. All inbound freight traffic, for connecting lines and for freight house and industries on North Western rails in the Chicago area is brought into Proviso.

The eastbound yards.

The receiving yard, consisting of 31 tracks, each holding from 90 to 100 cars, extends in a general north and south direction parallel with the Des Plaines Valley line and about a mile north of the Galena division main line, with a wye connection to the latter line. Trains from any of the incoming routes are pulled directly into the receiving yard, which lies on a practically level grade. A double-track line, built on a level grade, extends from the south end of this yard about one mile to the hump of the classification yard. The present traffic consists of from 2 500 to 3 400 cars daily. The number of classifications desired and the capacity of the yard determined that 59 tracks were required, varying in capacity from 44 to 96 cars. At the east end of the classification yard there is a forwarding yard of 21 tracks, each of 100 cars capacity, and also a repair yard that will hold about 120 cars.

Yard layout and retarders.

Having made an investigation of various yards, it was decided that car retarders were to be installed for the new classification yard, therefore a special study was made of the various factors involved. Tests of the wind for a year and a half showed that, at various seasons, the wind blew at equal velocity and frequency from all points of the compass; therefore, this factor was excluded. Approximately 90 % of the eastbound cars received are loads, the lading consisting of grain, coal, live stock, lumber, machinery, manufactured products and miscellaneous merchandise. Comparatively few cars have a gross tonnage of over 75 tons, and, therefore, this figure was adopted as the

maximum to be handled by the retarder system. When a car with heavier gross tonnage, such as 100 tons, is received, it is lowered part way down the hump before being uncoupled.

The question of rates and lengths of grades was determined by selecting a desired final speed of 5 miles per hour leaving the last retarder, with no acceleration at the hump. The formula for figuring the grades is an elaboration of the familiar one for falling bodies, $V = \sqrt{2gh}$, in which V is miles per hour instead of feet per second. Substituting any value in miles per hour for V, a table was worked out giving velocity heads in feet for any speed and from this the velocity a car obtains after traveling any distance on any grade was figured. The type of retarder selected

Fig. 1. — Retarder serving a group of seven tracks.

has, when fully closed, a resistance on a maximum loaded car, 75 tons, equal to 2.34 velocity head feet.

In order to reduce the number of retarders, the tracks were grouped in sets of six or seven tracks each, with a set of retarders on the lead to serve all of the tracks on the group involved. There are 30 car retarders in all, located as shown in the plan (fig. 2), and so arranged that a car on any route passes through eight retarders. The retarders, as well as the power switch machines, are controlled by machines in three separate towers, the area controlled by each operator being indicated on the plan.

The track layout was designed to bring the switches as closely as possible to the hump, the average distance from the crest of the hump to the clearance points on the classification tracks being 975 feet. The frogs are No. 8, with the

curvature split both ways. Experience showed that the resistance of curvature on curves under 12° was negligible for free-rolling cars; therefore, no compensation was made for curvature.

Considering the fact that all kinds of loaded and empty cars are to be handled at Proviso, an average grade of 2.14 % was adopted for the section from the crest of the hump to the beginning of the non-accelerating grade below the last retarder in each route. However, the average grade is not the only consideration, for the length of the different rates of grade at certain locations has an important bearing in expediting the movement of cars. The North Western used a 4 % grade for 160 feet down from the crest of the hump to secure a rapid acceleration of the cars, following which there is 230 feet of 1.2 % grade; then 100 feet of 3%; then follows 286 feet of 1.95 % grade, and finally 80 feet of 0.8 %, including the last set of two retarders. The total fall from the crest of the hump to the foot of the last retarder is 18.38 feet in a distance of 856 feet, giving an average grade of 2.14 %. From the lower end of the last retarder in each route a non-accelerating grade of 0.3 % extends through the several switches leading to the tracks in each group and throughout the classification tracks. At the lower end of the yard a rising grade starts about 200 feet from each clearance point, the purpose being to slow the cars down where the head-end of a train is established.

Method of operation.

As trains pull into the receiving yard, the waybills are handed from the locomotive to a messenger near the yard office, and are at once sent by a pneumatic tube system to the main yard office, about 1.5 miles away, requiring only 2.5 minutes in transit. After the train is in the yard, about 20 minutes is required for a crew of four car inspectors to look over the train and uncouple the air hose. During this time the waybills are checked for classification and the switch list is prepared on a teletype machine, being duplicated automatically by a teletype receiving machine in the humpmaster's office and in each of the three towers. An interesting feature is the enclosing of the teletype receiving machines in cases lined with celotex sound-absorbing material, the result being that the operation of the machines does not distract the attention of the towerman or those in the humpmaster's office.

As soon as the car inspectors complete their work a hump engine pushes the train to the hump, an interesting feature being that the approach from the receiving yard to the hump is on a level grade, so that an ordinary road locomotive can readily handle 100 cars in this service.

The movement over the hump is under the direction of the humpmaster, who operates the control lever for the humping signals. If necessary, the operator in the first tower can put the signals to red. A conductor, assisting the humpmaster, checks the cars against the switch list and directs the cutter, who « cuts » the cars as they pass over the crest of the hump. One brakemen is on hand to ride cabooses and cars loaded with such lading as milk, explosives, etc.

A loud-speaker telephone system, with sending and receiving equipment, located at the hump and in each of the three towers, is used to exchange information as to the movement of cars or concerning any change in the switch list. As the cars proceed down the hump, the operators follow the directions on the switch list to send each cut to the correct track and at the same time use the retarders to control the speed properly. While the classification is being made, the waybills are sent by pneumatic tube

from the main yard office to the departure yard office.

Speed of operation.

The classification yard is producing the desired results in eliminating yard delays, for no car lingers long at Proviso. An average of 30 inbound scheduled time-freight trains, each handling from 70 to 100 or more cars, arrive at Proviso daily, and second sections of some of these trains are run when the traffic requires. As high as 3 400 cars have been classified in 24 hours and on one occasion 100 cars were classified in 20 minutes.

About 60 % of the cars are destined for connecting lines and the remainder for delivery to freight houses or industries on North Western rails in the Chicago area. Several important through trains bringing grain, live stock and fruit from the West, machinery and

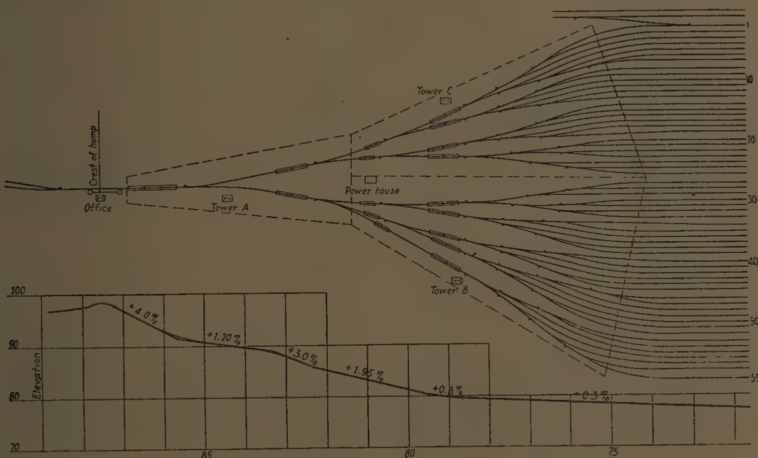


Fig. 2. — Track layout showing track grouping.

automobiles from Milwaukee and Kenosha, etc., are scheduled to arrive at Proviso between midnight and 7 a. m. All of these cars are classified and those for delivery on North Western rails are set at freight houses or industries in time for the opening of business, while the cars for connecting lines are pulled out by the connecting roads in time to make connections at Blue Island, Gibson and Colhour for 10 a. m. and noon departures to the East. The Mohawk, a fast « maintracker » freight train from St. Paul-Minneapolis, arrives at Proviso at 12.30 p. m. and all cars are classified and ready for departure by 2.15 p. m. in order to make deliveries and eastern connections.

An unusual feature is that some outbound traffic is classified in this yard. For example, cars from the Wisconsin lines that are destined for movement over the Galena division are sent over the hump and classified, several tracks being assigned for this business.

The retarder system, including the power switch machines and signals, was furnished complete by the General Rail-

way Signal Company. The control machines in the three towers are the latest panel-construction type. The levers for controlling the switches are at the bottom of the panels, indicating lights being located immediately above each switch lever. The next row of levers, each of which controls a retarder, are marked to show the four degrees of retardation that can be secured. A special button switch in each tower is provided to operate a klaxon horn located on the power house for calling the maintainer in case of trouble.

The retarders are the latest, all-electric enclosed type, operated by 220-volt d. c. motors. They stand normally clear and are moved to four other positions closer to the rail, giving the four respective degrees of retardation, at the last position the retarder shoes being at 4 inches opening. The switch machines are the model 6, high--speed type, operated by 110-volt motors and are so designed that the switch can be trailed through without damage to the machine. For the benefit of enginemen on trimmer engines, a two-indication color-light type switch target is located at each switch to indicate yellow when the switch is normal and lunar white when it is reverse. The targets can also be of some benefit to the towerman, although the same information is shown by lights above each switch lever.

Hump and trimmer signals.

The hump signals are the horizontal-type color-light units. The four indications are as follows :

Green : Hump fast.
Green and yellow : Medium speed.
Yellow : Hump slow.
Red : Stop.
Yellow and red : Back up.

On account of the approach to the hump being on a curve, it was necessary to provide nine hump repeater signals, seven of which were placed on wood poles on account of difficulty in securing proper footing for concrete foundations on the fill. The trimmer signal is of the same type as the hump signal and located back to back on the same pole as the hump signal.

Both the hump and trimmer signals, as well as all of the repeating signals, are controlled from a special hump signal control stand just outside the hump conductor's office. A four-position lever controls the hump signal and a two-position lever, the trimmer signal. Red, yellow and green repeater lights are provided on this control stand, so that the conductor can tell instantly what signal aspect is displayed. Also, the hump signal control is so arranged that the retarder operator in tower « A » can put the hump signal at red at any time by pushing a toggle switch on his machine.

Power is received in the power house at 440 volts, 3-phase. The two motor-generator sets are identical, each being in service during alternate eight-hour periods. The motor on each set is rated at 40 H. P., 440 volts, 3-phase, and the generator is rated at 265 volts at 56.75 amperes normal full load. However, on account of the special diverted pole construction of each generator, it can take a momentary load of 150 amperes without appreciably reducing the voltage regulation; in other words, the momentary capacity is about 40 kw.

The storage battery consists of 120 Exide type DMGO-9, 160 ampere-hour cells. Normally this battery floats across the 265-volt terminals of the generator and is thus fully charged at all times. The main battery is split and 115-volt taps are extended to the three towers to feed the switch-operating circuits which originate at the respective levers.

In case the load on the generator should exceed 150 amperes, as required by the retarders, the voltage will drop so that the battery will deliver current to meet requirements, thus preventing further voltage drop on the power-feed circuit.

Likewise, in case of an outage of the 440-volt alternating current incoming power supply, the motor-generator stops and the operation of the retarders as well as the switches is carried by the main battery. The switch repeater lever lights, the hump signals, and the loud speakers are normally operated on alternating current. Therefore, in order to continue operation of these functions during a power outage, a separate emergency motor-generator unit was provided. This machine has a 1.5-H. P., 110-volt, d. c. motor taking power from the main battery, and the alternator is rated at 750 watts at 110 volts.

The control and operating circuits between the towers, retarders, switches and power house are all run in underground wires and cables. The main runs are single-conductor insulated wires placed in Bermico fibre duct set in concrete. A concrete manhole is located in front of each tower, under each control panel case at each retarder layout, and near each switch, as well as at other points in the duct runs where required, there being a total of 51 manholes. The circuits from

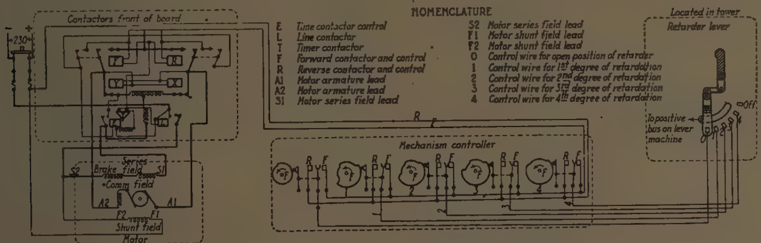


Fig. 3. — Typical retarder control circuits.

the control panels to the retarder mechanism, as well as from the manholes to the switch machines, are run in steel-taped parkway cable to pothead boxes near the machines, and single conductors extend through flexible metal conduits to the mechanisms themselves.

The conductors for the 220-volt d. c. circuit for the operation of the retarders are No. 000. The 110-volt power circuit from the switchboard to each tower for the switch machines varies according to the distance and load involved. The control circuits between the towers and the retarder panels are No. 14 conductors. All insulated wires and cable are Okonite.

Maintenance organization.

The maintenance of the car retarder system, including the power switches, retarders, teletype system and loud-speaker telephones, is handled under the direction of one leading signal maintainer, with one maintainer, one assistant maintainer and a helper on the first trick from 6 a. m. to 2 p. m.; a maintainer and an assistant maintainer on the second trick from 2 p. m. to 10 p. m., and a maintainer and an assistant maintainer on the third trick from 10 p. m. to 6 a. m.

At the beginning of each trick the maintainer makes a general inspection of all equipment to locate any unusual operation or defects, which are corrected as soon as possible. Having cleared up any minor defects, the maintenance men follow a regular program of work as laid out by the leading maintainer, who is on duty during the first trick. The first-trick force concentrate on the retarders, making adjustments to compensate for shoe wear, keeping all pins, bolts and nuts tight, etc. The proper opening of

the shoes is 4 inches when closed, and this opening is corrected to compensate for shoe wear by adjustment nuts on one of the main connections, which are moved about 3/4 inch to take up 1/4 inch on the shoe opening. On the retarders subject to heaviest duty, the outside shoes wear out in about six months, while the inside ones wear 18 months or longer. The replacement of shoes, the renewing of plates and pins, etc., are considered heavy repairs and this class of work is scheduled for Monday of each week, which is the day of lightest traffic.

The first-trick crew also handles the lubrication of the retarders, each retarder being lubricated every two weeks. An electrically-operated power gun is used to force the lubricant into the fittings, about two hours being required for one man to lubricate the 228 Alemite fittings on each retarder. Saturday is clean-up day, at which time the entire first-trick force is busy cleaning the retarders. A mixture of 50 gallons of black oil and 200 gallons of kerosene is made. Taking a pail full and a heavy broom, this mixture is spread all over the retarders and connections to clean off the dirt, to permit the oil to run down into the retarder mechanism as a lubricant, and to prevent rust.

The second-trick maintainer and his assistant take care of all the switch machines and the operating mechanisms of the retarders, including the motors. The switch machines are standard equipment, the maintenance being the same as on any interlocking. The retarder mechanisms are inspected to keep the commutators clean and adjusted for wear on the electric brake. Inspection is also made as to correct oil level in the gear case. The controller panels in the cases also require some attention to keep the contacts on the 220-volt circuit breakers clean, a fine file being used for this purpose.

The third-trick maintainer and his assistant take care of all inside equipment, including the switchboard, motor-generators, battery, etc., in the power house and also the control machines in the three towers. Battery readings are made and recorded, and the battery is maintained and kept clean. The motor-generators are inspected daily and kept clean and oiled.

The retarder system described in this article was planned and installed under the jurisdiction of J. A. Peabody, signal engineer, and under the immediate direction of S. E. Noble, assistant signal engineer.

[625 255, 625. 246 & 669]

Railroad use of aluminum alloys.

(From *Railway Age*, 8 February 1930 number.)

At a well-attended meeting of the Western Railway Club at the Hotel Sherman, Chicago, 20 January 1930, the use of aluminum alloys in the transportation industry was discussed and much pertinent information developed regarding the method of manufacture, economic advantages and workability of this relatively new material. Dr. P. V. Faragher, metallurgist of the Aluminum Company of America, described the manufacture of aluminum from clay-like bauxite ore mined in Arkansas, Georgia and Dutch Guiana, and cryolite, a milky white mineral somewhat like glass in texture, mined in Greenland. The general process includes purification of the bauxite ore by an alkali-reduction process to produce white aluminum-oxide which is subsequently dissolved in molten cryolite and aluminum deposited on the bottom of carbon-lined tanks by the electrolytic process. Doctor Faragher emphasized the large amount of electric power required for this operation; also, in the case of alloys, the careful heat-treatment necessary to obtain the desired physical properties, which further adds to the production costs. Following this address, A. H. Woollen, representing the engineering sales department of the Aluminum Company, presented the paper of the evening on railroad use of aluminum alloys, an abstract of which is included in this report of the meeting.

At the conclusion of the paper, an open discussion was invited and H. A. Brennaman, assistant works manager of the Pennsylvania Railroad at Altoona, Pa., commented briefly on the fabrication of aluminum alloy parts used in constructing eight suburban cars at the Altoona shops. Mr. Brennaman said that anticipated difficulties with the fabrication of these parts did not develop and that, with the proper pyrometer-controlled furnace equipment and reasonable care, no more difficulty was experienced in handling aluminum alloy parts than mild steel parts. He said that existing die equipment could be used equally well for both materials and that tests of aluminum alloy parts, pressed either hot or cold, showed no defects. Mr. Brennaman's remarks were corroborated by J. P. L. Sheets, general car foreman at the Wilmington, Del., shops of the Pennsylvania.

T. H. Pindell, general manager of the Alton & Southern, described the performance of aluminum alloy connecting rods and valve-motion parts on a switching locomotive which has been in service since 1926, giving entirely satisfactory performance with noticeably reduced maintenance cost. He also said that maintenance-of-way expense was reduced owing to the small amount of rail hammer with light rods and counterweights. J. W. Coulter, master mechanic of the Alton & Southern, estimated the weight reduction as a result of installing the aluminum alloy rods at a net saving of 42 % of the weight of equivalent steel parts and a saving in rod maintenance in the ratio of 3 to 5, as compared with equivalent steel rods. He explained this as being due to reduced weight of reciprocating parts, less unbalanced

weight in the driving-wheel counterbalances, and consequently a smoother operating locomotive with less rod-bushing and main-bearing wear. In response to a question, Mr. Coulter said that no loosening of bushings in the aluminum alloy rods was noticeable more than in steel rods.

Performance of aluminum in Illinois Central multiple-unit cars.

W. T. Kelly, representing the engineering department of the Illinois Central, outlined the performance of 260 multiple-unit cars, constructed with aluminum roof sheets, interior trim, conduit, etc. He said that no trouble has been experienced with these cars and that the use of the aluminum roof sheets of the same gage as steel sheets was particularly helpful in overcoming corrosion difficulties, formerly encountered with steel sheets, which required renewal sometimes as often as once in four years. In response to a question, Mr. Kelly said that in his experience the greater expansion of aluminum alloys as compared with steel, when the two materials are riveted together, is taken care of by a slight buckling of the aluminum. In no case, however, has this expansion been sufficient to shear rivets or give other serious difficulty.

Upon an invitation from the chairman, G. Van Dyke, manager of the special steel department of Joseph T. Ryerson & Son, Inc., said that an entirely new era of metal construction and application has been developed during the last few years, as indicated by the fact that a metal costing in the neighborhood of 40 cents a pound is being suggested as a substitute for other material which can be purchased for approximately 5 cents a pound. He said that corrosion-resisting alloys, heat-resisting alloys, alloys with high physical properties, acid-resisting alloys and many other metals have been developed, and it is gratifying to note that the makers of all these materials are approaching their sales problems from the standpoint of real service and economy to their customers. Mr. Van Dyke mentioned the use of Allegheny metal in dining-car kitchens where its non-rusting and tarnish-resisting qualities, and low upkeep cost, make its application particularly advantageous. In connection with heat-treatment, he said that the treatment of aluminum alloys within temperature limits of 930 and 960° F., is an indication that the use of modern metals is bringing with it an accuracy and exactness of handling which has taken the place of former guesswork methods. On behalf of the makers of all new metals, Mr. Van Dyke, appealed to the railroad men, when forming an opinion regarding the workability of any material, to determine first whether they have developed the right technique for handling, and if not, whether it may be entirely feasible to install the necessary methods and equipment, thus enabling the railroads to use the material to their profit.

How aluminum alloys serve railroads,

By A. H. WOOLLEN,
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The first attempt to reduce the weight of railway equipment by means of the application of the strong alloys of aluminum was in Illinois Central suburban service, the first cars being constructed in 1923. The operation of these cars being satisfactory, 215 additional cars were constructed in 1925, consisting of motor cars and trailers with aluminum used for roof sheets, interior finish, doors, conduit,

junction boxes, headlights and other small applications. The reduction in weight averaged 9 000 lb. per car.

About this time the Pennsylvania went even further and constructed eight suburban cars for the electric suburban service outside of Philadelphia with all-aluminum superstructures; that is, posts, carlines, outside and inside sheets, bulkheads, doors, and, in fact, everything above the underframe, with the exception of a belt rail which could not be manufactured in aluminum at the time.

There followed shortly thereafter the construction of 120 Chicago & North Western suburban cars having all aluminum sheets above the underframe. Both the Illinois Central and the Chicago & North Western have since put in service additional cars and have extended the use of aluminum somewhat over the original applications. One of the larger roads, after a thorough study of the cars in service, is now planning an even greater application than has yet been attempted, in which aluminum underframes and truck frames will be used. Many other roads have adopted aluminum for sheets and shapes in gas-electric car design on account of the desirability of weight reduction due to power-plant limitations.

At the present time, aluminum alloys cost from 28 cents to 45 cents a lb., or, on a square foot basis, 9 to 15 cents, as compared with 3 to 6 cents for steel. Therefore, it is necessary to justify this increased cost which amounts to from \$ 800 in a small city-type car to \$ 4 000 or \$5 000 in a large railroad car. It has been our experience that this extra cost can be reduced to a unit figure of 20 cents additional cost for each pound of weight saved.

Capital investment returned in fours years.

The most direct way to take advantage of weight reduction has been saving of propulsion energy. The cost of hauling around dead weight has been computed by various operating authorities and varies between 5 and 10 cents per pound per year on street railways and 3.5 cents on heavy electric traction lines. Assuming that 20 cents is the extra cost and 5 cents the saving, in four years the aluminum has paid for itself and after that time it is helping to increase the net earnings of the company.

The use of aluminum can be justified by the light weight of the cars which can be used to promote higher schedule speed so that fewer cars may be used for a given service.

The aluminum car is the ideal safety car; its light but strong framework has shown a remarkable ability to absorb impact loads without distortion and when the impact does exceed the yield point of the metal, there is a marked tendency for the structure to hang together. Gusset plates, webs of channels, I-beams and built-up girders will bend but do not tear as do most grades of structural steel. The low modulus of elasticity is probably responsible for these phenomena but the net result is a safer vehicle.

When designing an aluminum car, the same basic principles apply as with any other construction material. Physical properties of the various alloys are well known and are about the same as mild structural steel, except that the modulus of elasticity is used as 10 000 000 in place of 30 000 000 and the coefficient of expansion is about twice that of steel.

Construction of aluminum cars.

The construction of aluminum cars in car builders' plants does not offer any difficulties that cannot be overcome in a modern shop. Punching, shearing, machining, riveting are all performed with the usual tools available for steel. Bending cold must be watched and the particular qualities of the various grades and tempers of aluminum alloys known, but as soon as the shopmen accumulate expe-

rience, this problem offers no objection. Hot bending or forming is the only special feature of aluminum alloys to require particular attention by shop forces, as the technique varies considerably from that of steel. Temperature control is essential, and heating facilities must be provided, differing from those in common use for steel. The strong alloys of aluminum will begin to anneal at 450 to 500° F., and if heated beyond that point must be reheat-treated to regain their original strength. Heat-treatment requires a furnace which can be held at from 930 to 960° F., from which the material is quenched to room temperature. However, the necessary information is available to every shop, both from printed matter and by personal instruction, so that in a short time the shopmen can manipulate the aluminum alloys in an efficient and economical manner.

The welding of aluminum can be accomplished by the usual oxy-acetylene torch, and development work is in progress with electric-welding apparatus which promises some excellent results.

Maintenance factors.

The maintenance of the aluminum car should not be any higher than that of the car constructed of materials now standard, and there is considerable indication that we may expect a lower maintenance cost for there will be no tendency for the paint to peel off due to corrosion such as is common in a steel car. If the original paint job is properly done, it would appear that a periodical freshening of the varnish coat should keep the car in good shape and practically avoid a complete burn-off, thus saving \$ 75 to \$ 100 per car per year from this source alone. The replacement of aluminum parts damaged in accidents will cost more than steel, but the damaged parts can be sold for scrap at from 40 to 60 per cent of their first cost.

Cars built of aluminum show no corrosion after two to five years of severe service which leads to the assumption that, as far as corrosion is concerned, the aluminum car will last practically indefinitely.

The shop equipment necessary for the proper maintenance of aluminum cars will not differ from that now used, with possibly two exceptions — a heating furnace and a portable pyrometer. An electric furnace costing \$ 4 000 or \$ 5 000 is preferred, but this would not be necessary until a large amount of regular repair work became necessary, as the ordinary blacksmith forge could take care of most of the jobs of straigthtening or bending structural shapes required for repair work. It would be necessary, however, to purchase, at an early date, a portable indicating pyrometer which would cost approximately \$ 50. This instrument would permit the handling of aluminum with greater ease in ordinary equipment and prevent damage by overheating.

Aluminum tank cars, locomotive rods, etc.

There are numerous other railroad applications of aluminum alloys. Probably the most important of these at the present time is the aluminum tank car. Between 75 and 100 of these cars will be in service on American railroads within the next six months transporting glacial acetic acid, formaldehyde, turpentine and other commodities which may be transported in aluminum cars without damage to car or commodity and thus save the additional cost of lining a steel car. In every instance the aluminum tank car is justified on the basis of first cost, and the savings which it makes for its user are available from the start.

Another use for aluminum has been developed and is still in the experimental stage. I refer to the aluminum connecting rods for steam and electric locomotives and aluminum valve gear parts for steam locomotives. We have had aluminum

main and side rods on the Alton & Southern switching locomotives for several years and the reduction in weight of these reciprocating parts effects material savings in maintenance of both locomotives and permanent way structures. With such an important part of the locomotive as the connecting rods we want to be sure that a design is developed which will take advantage of the physical properties of the strong aluminum alloys in such a way as to provide equal, if not greater, safety with the aluminum rods as with the present type of construction. We have demonstrated, to our own satisfaction at least, that the rods in switching locomotives are satisfactory, safe and economical, but before going on to the main line, we felt it essential to conduct laboratory tests on the largest type of freight locomotives which would travel at sufficient speed to introduce substantial factors of centrifugal force. We are now making a set of rods for a heavy Mikado type locomotive and intend to study its performance in a large railroad testing plant. This locomotive will be operated under normal and maximum service conditions and, by means of recording instruments applied directly on the rods, we will have an exact knowledge of the conditions existing in the vital parts of the rods. The locomotive will then be taken out on the road and a service test made. It is hoped that by the June convention of the American Railway Association, Mechanical Division, our tests will be completed and we will be in a position to say to you, Gentlemen, that aluminum side rods, main rods and valve motion parts may be safely and economically applied to any standard steam locomotive.

Aluminum furniture past experimental stage.

One of the most useful applications of aluminum products on the railroads has been the furniture, developed originally for the Pennsylvania. Aluminum dining-car chairs have found wide use and are manufactured in the Buffalo, N. Y., plant to suit the requirements of the railroads. Alcraft aluminum furniture, as it is called, is available in almost any finish and upholstery to meet the desires of the railroads and car builders and shows immediate returns in low maintenance cost.

The motor transport industry is growing by leaps and bounds. Highway construction is becoming such that high-speed vehicles are permissible and are being increasingly used by the railroads. In order to operate high-speed vehicles safely, a high rate of acceleration and retardation is necessary. The use of aluminum construction permits an increase of pay load for a given wheel limit, increased acceleration with a given power plant, greater braking effectiveness and the permanent protection offered by the all-aluminum fire-proof, corrosion-proof, body construction.

The development of the motor coach has been so rapid that builders have figured on a four-year life as all that is necessary to build into a coach body because obsolescence would retire the body before it wore out, but the railroads have found it necessary to build railroad cars for a life of 20 years or more.

Additional miscellaneous uses of aluminum and its alloys in the transportation field are: Transmission lines of aluminum cable, steel reinforced; Albron powder as a base for aluminum paint for signals, bridges, shops, roundhouses, etc.; architectural material, including corrugated sheet, factory sash, casements, etc. Enginehouse smoke jacks have shown that the corrosion from the stack gases will not proceed as rapidly when made of aluminum as of other materials. Aluminum conduit is finding increased use for protecting wiring on locomotives, cars, in shops and enginehouses, and for similar reasons.

CURRENT PRACTICE.

[625 232. (.42)]

London and North Eastern Railway first class sleeping cars.

Figs. 1 to 3, pp. 81 to 83.

The sleeping cars recently put into service by the London & North Eastern Railway Company were distinctly modern as regards their interior decoration. Two further cars have now been completed at the Doncaster Works to the designs of Mr. H. N. Gresley, C. B. E., the Chief Mechanical Engineer, in which a more elaborate style has been adopted, and these cars make a complete break away from anything previously done.

The interior decoration of the berths was prepared by Sir Charles Allom in conjunction with Mr. H. N. Gresley.

Until recently, polished wood has been largely used in the interior decoration of sleeping car berths. In order to meet modern taste the interiors of the berths of these cars have been painted.

The berth walls are panelled and moulded, the panels being finished in a light tone of bluish green; the styles and surrounds are a slightly deeper tone of the same colour. The panel mouldings are picked out in a medium tone of warm biscuit colour, and the capping mouldings above the panelling have a deeper tone going towards a fawn. The frieze above the capping is coloured in a lighter shade of the panel moulding colour.

The ceiling mouldings have been arranged to form a sunk panel. The ceiling is treated in white, broken with the pale frieze colour to harmonize the scheme, and the cornice is a light biscuit colour picked out with the green of the panels.

The colours have been so skilfully chosen that each berth has the appearance of a small well appointed bedroom in an hotel. Each compartment is provided with a bedstead, the head and foot being of walnut. The bed is fitted with a Marshall's patent box spring mattress with a horse hair and new wool overlay, and blankets of a soft green colour harmonizing with the general scheme of the coach. The lettering is of fawn. Bedspreads of linen taffeta in a light biscuit colour are provided embroidered with the initials L. N. E. R.

The floor of each berth is covered with Persian design close covered carpet having a ground of dark blue. The corridor is covered with similar carpet having a line border all round.

Hot and cold water is supplied to each berth which has a wash bowl fitted in the corner near the window, a commode being carried in the pedestal below the basin.

A large mirror is placed centrally on the intermediate partition and a full length mirror is fixed on the corridor door. A folding table is provided on the intermediate partition and another one to take a tea tray is placed over the bed. A shelf is fitted over the bed head and the top of this; the tops of the folding tables and the pedestal lid are all covered with india-rubber.

Fig. 1.

Blinds have been done away with and a sliding shutter has been fitted inside each berth window. The shutter is louvred and draught proof and slides into a pocket formed in the body side when not required. The window is fitted with a frameless light and a glass louvre ventilator, both of which can be operated when the shutter is closed; air may therefore be admitted to the com-

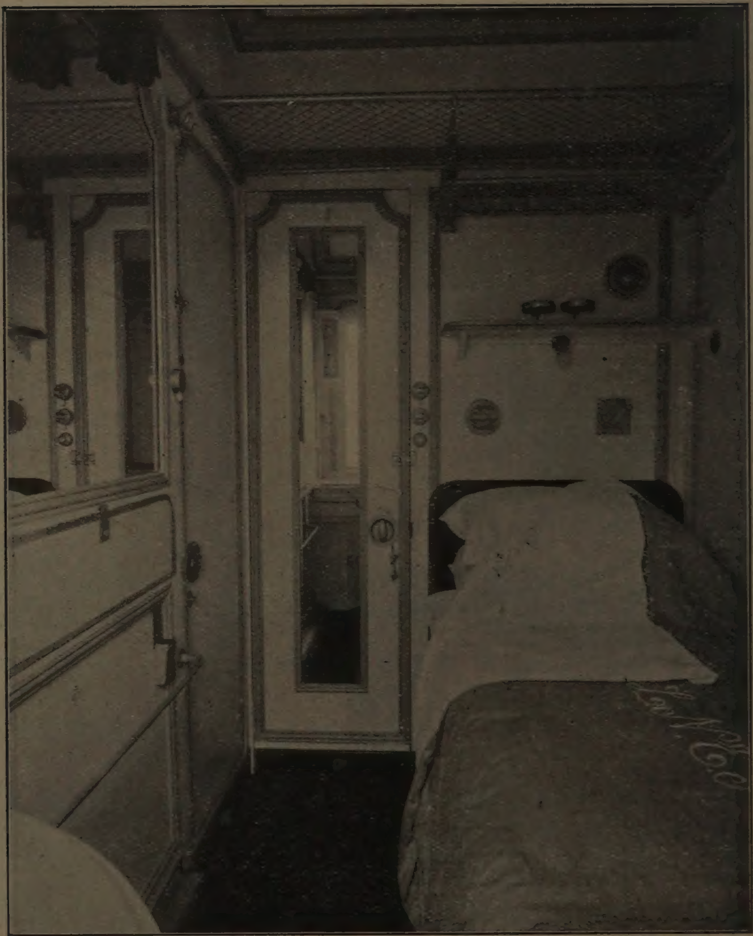

Fig. 2.

partment without draught through the louvred shutter.

A double net rack is fitted above the bed head and a single one over the foot.

The lighting is by means of a 30-watt opal lamp carried in a special fitting in the centre of the ceiling without any shade; this lamp may be dimmed to serve as a night light. A reading lamp is fitted under the shelf over the bed head,

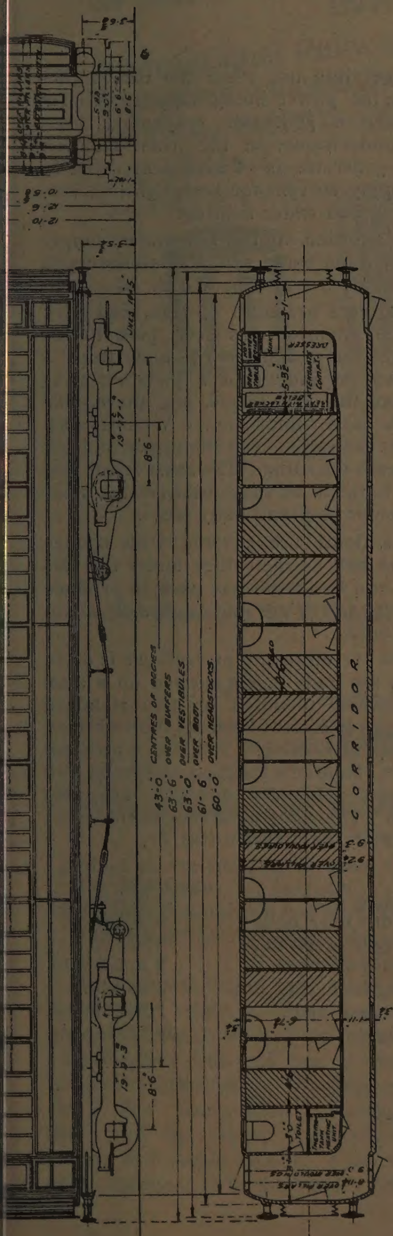

Fig. 3.

and switches are conveniently placed so as to be under the control of the passenger when lying down. There is also a lamp enclosed in a silk shade on the partition over the mirror.

A special coat and trouser hanger is provided on the partition over the bed, the hanger is hinged so that it can be pulled out when needed. The usual hat and coat hooks are fitted on the opposite partition.

All doors are fitted with recessed handles and sliding bolts; they are also fitted with hooks and staples by which they can be fastened back.

All metal fittings are chromium plated.

A steam-heated radiator is provided on the partition below the mirror, the regulator controlling this being placed near the bed head.

An extractor ventilator it also fitted, the control lever for this being adjacent to the other control fittings.

Main ventilation and heating.

In addition to the ventilation provided by means of window and extractor ventilators, the car is fitted with pressure ventilation. A small nozzle is fitted on the partition above the shelf over the bed head, this nozzle being so arranged that it can be set to deliver cold, warm or hot air in quantity and direction as desired by the passenger. The air supplied to each berth is drawn through a filter by a noiseless electric blower fan at one end of the corridor. Part of the air is passed through a heater fitted in the roof of the corridor. Plywood ducts are fitted, one for cold air and one for hot air, the hot air duct being fully insulated to prevent as far as possible any loss of heat.

Toilet compartment.

A toilet compartment is provided at one end of the corridor. This compartment is lined out with teak matchboard-

ing up to the waist line, above which it is finished in white « Vitrolite ». The pedestal hoppers are of the ordinary London & North Eastern type. In order to indicate to passengers whether the toilet is vacant or engaged, an illuminated indicator is provided on the end of the body, visible from any part of the corridor. The indicator consists of a piece of mirror, the top half of which, when illuminated, reads « Toilet vacant » and the lower half « Toilet engaged ». The illuminated letters are obtained by carefully removing the opaque backing without destroying the silver, and painting over the lettering so formed a thin coat of white paint, so that when the electric lamps are extinguished the lettering is practically illegible. These lamps are controlled by a switch operated by the bolt on the toilet door.

Attendant's compartment.

The attendant's compartment is at the opposite end of the car, and is fitted with the necessary cupboards for crockery, sink, etc., to enable light refreshments to be served. The apparatus for supplying hot water to the berths is also fitted in the attendant's compartment and forms one of the principal features of the car. The water is heated by electricity, and thereby it has been possible to entirely dispense with gas. The hot water heating system involves two distinct electric circuits, a 220-volt circuit being fitted so that the car can be plugged in to the station supplies for preheating the water, 220 volts being the standard voltage used on the London & North Eastern Railway for electric cooking, etc.

The low voltage (24-32) circuit is brought into use when the car is running, the power being supplied from a belt-driven generator suspended from the underframe, in the usual manner. This generator is of sufficient capacity to supply current for both lighting, ventilating and water heating.

In addition to the hot water supply heater a hot water urn, a small saucepan and kettle are also provided.

The cars are built of teak, and very special attention has been paid to the elimination of noise. The body itself is carried on india-rubber pads isolating it from the steel frame, and the double floors have compressed « Wadnit » asbestos felt in between the upper and underneath boarding. The same felt is also used to fill in all space between the inner and outer roof and body sides.

The floors are covered with sponge rubber half an inch thick under the carpets, and the result has been to produce sleepers which are quite unusually silent in running.

The overall length of each car is 63 ft. 6 in., the body being carried on a steel underframe mounted on two standard London & North Eastern four-wheeled compound bolster 8 ft.-6 in. wheelbase bogies. Standard Pullman vestibules and buckeye automatic couplers are also fitted. The general arrangement is as shewn on the diagram (fig. 3).

The main dimensions are as follows :

Length over body . .	61 ft. 6 in.
Width over body . .	9 ft. 3 in.
Length of berth . . .	4 ft. 6 in.
Width of berth . . .	6 ft. 7 3/4 in.
Length of bed. . . .	6 ft. 4 in.
Width of bed	2 ft. 6 in.
Weight	38 1/2 tons.